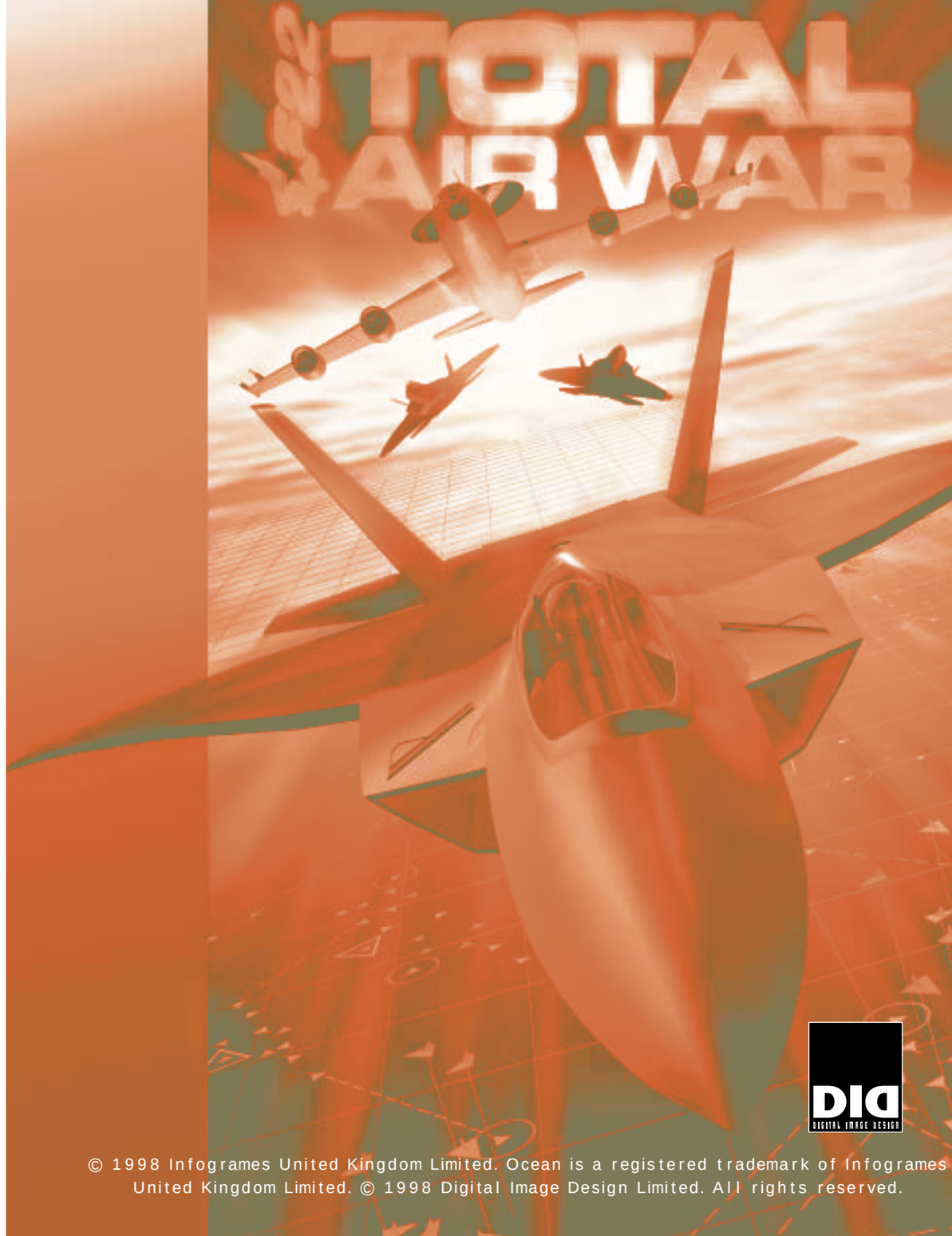

“There’s no fighting in the War Room”

President Merkin Muffley, Doctor Strangelove, 1964.

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Copyright Notice

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Warrington, Cheshire. WA2 7NR

Data Validity

All data for TAW have been secured from public sources. DID stress that all simulated elements are our interpretation of the facts, and are intended for entertainment purposes only. Because the F-22 Raptor is still in development, some of the systems represented in the game may not be associated with the real plane. Any trade names or trade marks are the exclusive property of the respective manufacturers.

Caution

The CD-ROM that holds TAW can be damaged by mishandling. We recommend that even if you intend to run TAW directly from CD-ROM, you perform the full installation to hard disk once and make a back-up copy using back-up software.

EPILEPSY WARNING

A very small percentage of individuals may experience epileptic seizures when exposed to certain light patterns or flashing lights. Exposure to certain light patterns of backgrounds on a television screen or while playing computer games may induce an epileptic seizure in these individuals. Certain conditions may induce undetected epileptic symptoms in persons who have no history of prior seizures of epilepsy. If you, or anyone in your family, has an epileptic condition, consult your doctor prior to playing. If you experience any of the following symptoms while playing a computer game: dizziness, altered vision, eye or muscle twitches, loss of awareness, disorientation, any involuntary movement, or convulsions, IMMEDIATELY discontinue use and consult your doctor before resuming play.

Pack Contents

Accompanying the manual inside this box you will find one CD-ROM, a guarantee card and a keyboard layout diagram. Please remember to return your guarantee card, and answer the questions. This gives us clues for developing the products you want in the future.

Queries

If you should find either the program or the documentation unsatisfactory in any way, don't hesitate to drop us a line detailing in full the reasons for your dissatisfaction. This will help us to avoid repeating any similar problems in the future. Opinions and complaints should be sent to:

The Project Director, TAW,
Digital Image Design Ltd.,
Tannery Court, Tanners Lane,
Warrington, Cheshire.
WA2 7NR

Getting Started

Getting Started

To install and run Total Air War (TAW), follow the steps below. If you have problems with the installation, or subsequent use of this product, please contact us on one of the following telephone/email numbers;

Telephone Support

Game Installation

The TAW set-up program will run automatically on inserting the game CD ROM disk into the CD ROM drive of your computer. If TAW is already installed on to your computer then you will be asked if you want to run the program, alter the game configuration or re-install the game.

In order to play TAW you must already have DirectX 5.2 installed on your computer. If required, the TAW set-up program will install DirectX 5.2 automatically .

Installation Steps

1. Place the 'Total Air War' CD-ROM in the drive of your computer. The set-up program will run automatically.

2. After clicking 'Next' on the copyright window you will be asked if you want to install DirectX 5.2. It is recommended that you install this as TAW will not run without DirectX 5.2 (or above).

3. You will be asked what kind of installation you would like for TAW. There are three types:

- Typical (the default setting)
- Compact
- Custom

The 'Typical' option will copy all data files on to your hard disk. This option requires the most hard disk space but offers the fastest loading times for the installed simulation.

The 'Compact' option copies only the files required to run the game. If you use this option you must have the TAW CD-ROM disk in your computer's CD-ROM drive when you play the game. This installation type has slower loading times than the 'Typical' option, but takes a lot less hard disk space.

The 'Custom' option is for advanced users, and allows you to specify what files are copied on to the hard disk.

4. Next, you have the option of installing either the Direct3D or Glide (3Dfx Voodoo) executable. If you have any doubts about your graphic card hardware, select the default option, Direct3D.

5. The set-up program installs TAW to '\Program Files\DID\Total Air War' by default. To change this, select a new location by clicking on the browse button.

6. The set-up program will then ask which folder in the start menu you wish to place the program shortcut. It is recommended that novice users select the default setting by clicking on the 'Next' button.

7. You will now be shown the options on screen that you have just selected. If you are happy with your choice then click 'Next' and

TAW will start to install.. If you are unhappy with your selections and you want to change them then keep pressing the 'Back' button until you reach the option you wish to change.

8. The set-up program will now copy the TAW files on to the hard disk of your computer. The computer's progress can be seen on a blue bar in the center of the screen. When it reaches the right hand side, the file copying has finished.

9. The set-up program will now ask what controller type you want to use to play TAW. DID recommends that you play the game with a joystick to experience TAW at its best. If you do not have a joystick then you can control your aircraft using the keyboard.

10. The set-up program will then ask for sound options you want while playing the game. There are three options:

- Sound Effects
- Music
- Speech

11. You will be asked if you wish to look at the Readme file. The readme file contains necessary last minute alterations to the manual and other useful information. We recommend you browse through it before playing the game.

12. You have now installed Total Air War. Before you can play, you will have to reset windows to ensure it operates correctly, so click on the 'Finish' button. Your machine will then restart. To run TAW follow the steps in the next section.

Starting Total Air War

To start the game, press the Windows 'Start' button and from each subsequent menu, select; Programs, followed by DID, followed by Total Air War and finally Total Air War.

Configuration

If you wish to re-configure the game after installation place the game CD-ROM in to the CD-ROM drive and select 'Change Setup of Installed Game'. Click the 'Next' button and follow the on screen prompts.

Changes to the Published Manual

Amendments to this manual and information about specific hardware support can be found in the readme.txt file.

To Uninstall Total Air War

To uninstall the game, press the Windows 'Start' button and from each subsequent menu, select; Programs, followed by DID, followed by Total Air War, and finally, Unintstall Total Air War.

Quick Start and Using the Interface

Once the game is installed, choose Total Air War from the start menu, or if you have created an icon, double click on the TAW icon on your computer desktop to start the game.

Login Screen
You will be presented with the Login Screen first, where you must enter your name and preferred call sign. Once you have completed the login process, TAW will load and take to straight to the main interface.

The Main Interface
From the Main Interface, you can run the following sections of the game:

Campaign
Choose one of ten dynamic scenarios for the new TAW campaign.

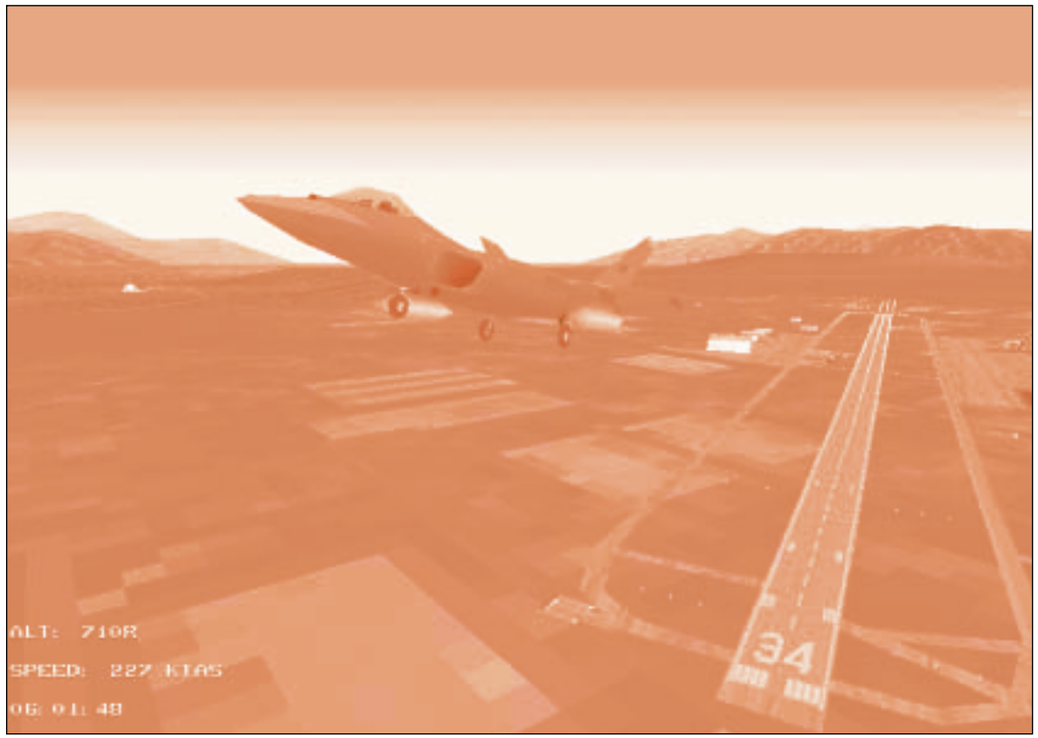
Training
Learn the tricks of the trade in realistic training missions.

Custom Combat
Hand-edit intense head-to-head combat missions for instant action.

Multiplayer
Link your computer and fly with your friends in co-operative and head-to-head missions.

ACMI
The ultimate debrief. Replay every intimate detail of your mission in the ACMI (Air Combat Maneuvers Instrumentation).

Options
Options contains a selection of user configurable options, including graphics and sound complexity.



Quit
Select Quit to leave the game and return to your desktop.

Please refer to subsequent sections of this manual and the Online Help for information about flying the F-22, the dynamic campaign, AWACS and the other game components that constitute Total Air War.

Strap on a Jet...

If this is your first mission, select one of the Free Flight Training missions and once within the cockpit, press SHIFT S until you are airborne. Welcome to the F-22 Air Dominance Fighter in Total Air War.

Overview

Welcome to DID's Total Air War (TAW). TAW is an extremely sophisticated aerial campaign and flight simulation program expertly integrated into one very compelling game. It is the next step in Digital Image Design Ltd's proud tradition of award winning military flight simulation products.

TAW is as its name suggests – a total, integrated air campaign based on plausible (but fictional) international conflicts in the Red Sea theater. It is a fight for aerial supremacy that will test your understanding of the chief tenets of modern strategic air power planning and execution. Don't worry though, there is a lot of interesting theory and expert advice contained here to help get your campaign started off in the right direction.

In TAW, your *real-time* campaign will run continuously until the conflict has reached a final resolution. This conclusion will be based on several real-world variables being monitored by the campaign engine. Perhaps it might be that the allied losses have been too high, or that enemy forces have failed to realize their campaign objectives within their projected time frame, just to name a few. Any one of these or many other real-world factors will influence and ultimately force the winning or losing decision model.

All aircraft missions within the campaigns are created *dynamically* in response to high-level scenario decision-making processes made possible by the next generation of campaign artificial intelligence. These missions will vary in complexity and reflect the current strategic objectives, each of which will adhere to current USAF strategic doctrine. Thus the campaign you embark on will be *non-linear* in nature which, as no missions are scripted, ensures that no scenario will ever play the same way twice. Your control of the campaign will be accomplished in one of two direct action roles, one as a U.S. Forces Battlespace Commander aboard the AWACS airborne command and control platform; and the other as a U.S. Air Force pilot, flying the advanced F-22 Air Dominance Fighter aircraft. Both roles will test your ability to focus on achieving your strategic objectives through a balanced use of proper force and sound tactics.

This section will introduce you to TAW and provide you with a brief glimpse at some of the fun and challenges that await you!

Welcome to Total Air War

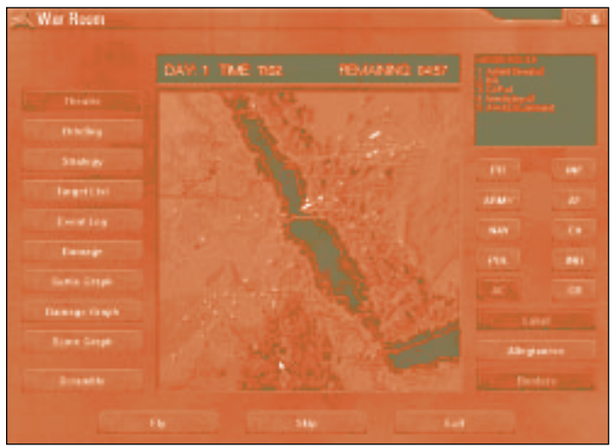
Login

TAW opens with the Login screen from which you enter your name and callsign. The dialogue box also displays your Squadron patch and pilot photograph. You can customize the Login screen by adding your own patch insignia and pilot photograph. A scoring and award system enables you to track your progress in each campaign and watch as your "simulated" U.S. Air Force career progresses.

Ten dynamic campaigns

Campaign Scenarios

The Campaign scenarios are the heart of TAW. They are comprised of ten separate and distinct situations involving the nations in the Red Sea theater. These scenarios vary in complexity and duration starting with border disputes and progressing in scope and complexity to multi-national regional conflicts. Accurate modeling of air, ground and sea forces, based upon predictions of the balance of power in the early decades of the next millennium, means that you can fly alongside many different aircraft in many different national markings. These can include such diverse groups as Yemenis Su-35s, Egyptian Rafales, or maybe even British EF-2000s!



Operational center - the War Room

War Room

The War Room is your active command headquarters screen for playing out the selected campaign scenario. From the War Room, you can monitor your campaign as it unfolds in real-time. Allied aircraft missions will appear and move as they carry out their orders, such as; patrolling friendly borders or flying offensive missions to strike deep behind enemy lines. Enemy and neutral forces are also visible from the War Room. However, without the assistance of the AWACS in conjunction with ground-based EWR sites, the enemy's intent may be difficult to determine. In the War Room you can watch as targets within the theatre get engaged by opposing forces.

The War Room uses information display filters to assist you in understanding the current status of your campaign by displaying target damage information on the map. This will help you determine any targets relative strategic importance as the campaign progresses. The status of your Allied offensive can be determined by looking at the graphic display of gains and losses from within the War Room. The information on these graphs is updated every hour, as intelligence feedback is tabulated. From your position in the War Room, understanding and use of current US Air Force doctrine will play a key role in determining a winning strategy. Take command as key elements of enemy infrastructure are rendered in-operative and enemy aircraft and C4 nodes are targeted. Successful players will see the end result of air supremacy being achieved.

Total Air War – Overview

AWACS

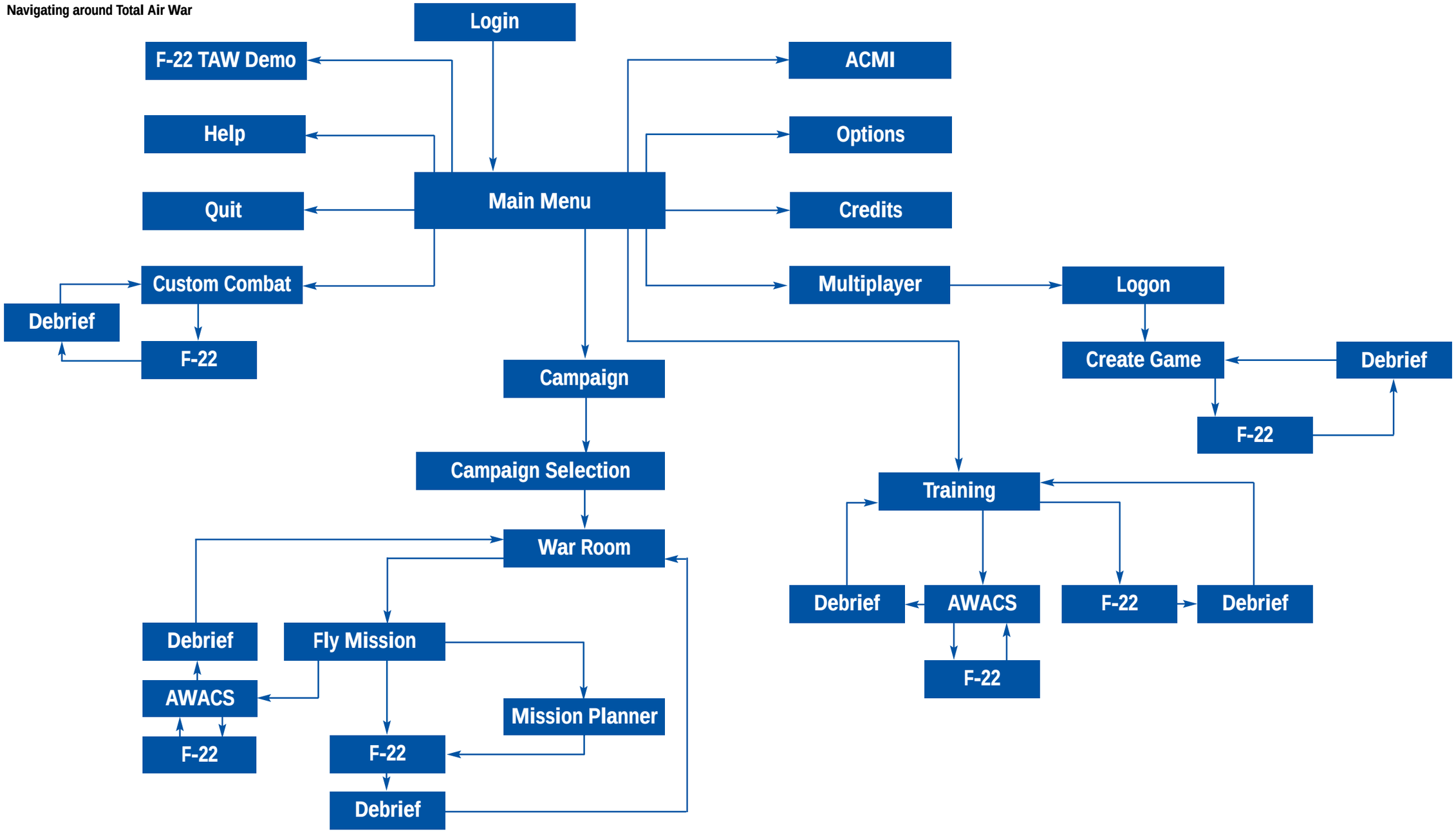
First introduced in F-22 Air Dominance Fighter the AWACS plays a pivotal role in directing your airborne campaign strategy in TAW. Networked with the ground-based EWR network, control from the AWACS makes it possible to detect and identify enemy airborne forces as soon as their intent can be classified as hostile. The role of the AWACS commander is to bear full responsibility for maintaining the integrity of all allied airspace. With the simple drag-and-drop control interface, vector friendly aircraft assets to intercept in-bound bandit aircraft, identify unknown airborne targets and clear attack routes deep into enemy territory for allied strike flights. The real-time, constant generation of allied and enemy flights by the TAW campaign engine ensures that your role as the AWACS commander can at times be a complex and demanding task.

The heart of the C4 network

The E-3 Sentry, airborne command and control

Total Air War – Overview

Navigating around Total Air War



Total Air War – Overview

'On the fly' mission generation

F-22 Missions

The player wanting to take part in the campaign as an F-22 pilot now has three methods of getting into cockpit. The campaign engine will launch scramble missions as necessary to intercept enemy aircraft as they penetrate allied airspace. If you opt to fly a scramble mission, you will be launched directly into the cockpit of a ground alert F-22, waiting on the runway of an allied airbase ready to intercept inbound enemy aircraft. While commanding the AWACS, you can double-click the mouse on any allied F-22 and immediately assume control as the pilot in command of that aircraft. You can also choose to fly an F-22 mission from a current list of Air Tasking Orders (ATO) displayed in the Mission Selection Screen

F-22 Mission Selection

At any time during the campaign, you can fly an allied F-22 mission off of the latest ATO from within the War Room. The "Fly" request will search the ATO and then display all Allied F-22 and AWACS missions currently ready for departure and will present them in the Mission Selection interface. You will note that all airbases will not have the same type of mission available for you to fly. The forward area bases, which often come under attack from enemy forces, will be limited to CAP and defensive type missions. The airbases further away from the front, deeper into allied territory should usually be safer from hostile attack. These bases will be providing more of the offensive type of missions. Airbases furthest from the front line will house the E-3 and E-8 aircraft along with any other High-Value Asset (HVA) and experimental aircraft which are best hidden from the opposing forces eyes. By selecting a cross-section of missions from the ATO, each of these airbases will have missions to fly. If your rank allows, you can choose to fly any one of a diverse range of missions, acting in a number of different tactical roles. Unlike F-22 Air Dominance Fighter, none of these air missions are scripted which again ensures that no two missions will ever be the same.

Mission Planner

TAW brings you one of the most thorough, yet intuitive mission planning suites ever released for a flight simulation. Once you have selected an F-22 ATO mission from the Mission Selection interface you can choose to edit the mission with the Mission Planner. The Mission Planner enables you to edit almost every aspect of the selected mission's parameters including your target choice, supporting aircraft types and weapon selection.

The Mission Planner is powerful enough to allow you to edit and fine-tune almost every variable within the campaign engine generated ATO mission. You have the ability to choose a different target if you don't wish to attack the one assigned to you by the AI. Realize that not taking out your campaign assigned target could have serious and far-reaching implications on the outcome of the real-time war which is going on around you. The pre-planned waypoint route can be changed to avoid SAM and EWR sites as you see necessary for mission accomplishment. The altitude at each waypoint can also be changed to better integrate other supporting missions, such as your strike flight which will need to go in low to take full advantage of the support of high altitude wild weasel and escort flights.

It is also possible to add and delete flights of aircraft from your mission while using the mission editor. You can choose to fly with extra fighter escort flights or if your prefer more of a challenge, you can opt to fly without any other support aircraft. The Mission Planner lets you arm your aircraft with a range of suitable weapons packages based on the flights mission role. These weapon loadouts reflect the best-choice option for that respective weapons platform. For the F-22 you have the option to select individual weapons for each pylon of your available wing and fuselage pylons.

All of these mission planning tools use an intuitive point-and-click interface. Additionally you also have the option to use the automatic Mission Planner feature to automatically generate mission components, reducing your planning workload if you so desire. All of these advanced features are now available to you as part of the TAW Mission Planner, which is one of the most comprehensive planning tools currently available.

Route planning in the Mission Planner

A full arsenal of weapons is at your disposal

Enhanced Multiplayer

TAW Multiplayer introduces a number of new game-play features including a new range of co-operative multi-player missions. Multiplayer also supports the Custom-Combat Generator, allowing the game server to design specific head-to-head or co-operative missions.

Fine tune your own instant action missions

Custom Combat Generator

The Custom Combat Generator allows players to easily create a quick Air-to-Air or Air-to-Ground combat sortie. Getting into the cockpit of your F-22 is only one click away after you have decided the parameters for your fight. Take on a flight of deadly Su-35s, or MiG-29Ms with GUNS only! Custom Combat lets you experiment and find out for yourself how it feels to fight other airborne hardware 1-on-1 or 2-on-2, etc… the choice is yours to make.

Record your combat and analyze your skill in ACMI - a simulation of a real-world training aid used by the military

(ACMI) Air Combat Maneuvering Instrumentation

The USAF operates several training establishments where data on aircraft and weapons positions are transmitted from fighters practicing combat, and relayed to ground stations where they are recorded. When the pilots land and gather for debriefing, the data are replayed in a simple 3D graphical form, enabling student pilots to learn from their mistakes. The dogfighting action can be slowed down, speeded up or frozen, to reveal every move down to the smallest detail. After much demand from our customers, we have included an ACMI facility for the player to record combat maneuvers and compare them as an aid to learning about modern air combat. Like the real thing, our ACMI collects data from the player's aircraft and allows a graphical portrayal of that data to be replayed afterwards.

Player Views

A variety of player views can be selected both within the virtual F-22 cockpit, outside the aircraft and views of the F-22 instruments. Padlock views provide a more realistic view of the world and can be locked to a desired view, or object.

Total Air War – Overview

Smart Views

In a simulation, internal, external and God's-eye views allow the user to see several different aspects of an object or the world; in TAW there is plenty to look at, with hundreds of vehicles moving simultaneously, plus sites of antiquity and other tourist attractions. In real military simulation, this function is called a 'Stealth View'. In our simulation we call the feature 'Smart Views'. This technology places virtual cameras on any aircraft or ground object and links them together in a way that is both informative about the subject and entertaining. It is like watching a movie, except that you direct the action.

For additional details, see the Smart Views chapter of this manual and the Online Help. In addition, see the supplied Key Card for keyboard combinations necessary to operate all the views.

There is plenty of action in Total Air War. Smart Views let you see it all.

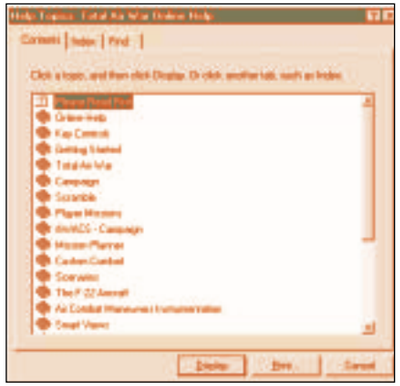
Your route to greater flying skills

Training

The Training section of TAW adheres closely to real military practice and tactics and is intended foremost as a training area in which the new user can build up his knowledge and skill before going to war in Campaign. For variety, the Training missions are written so that each contains more than the aircraft and targets necessary to learn the specific lesson.

Online Help

The Online Help is a specially prepared interactive manual, accessible from within the Main Interface under the Help button. The Online Help enhances the contents of the manual by making it interactive. For additional details, see the Main Interface of Total Air War (Help button) and the Online Help chapter of this manual.



Easy access to help, when you need it

Campaign

"One cannot doubt that flying…must in the future exercise a potent influence, not only in the habits of men, but upon the military destinies of states." **Winston Churchill**

Introduction

Total Air War (TAW) uses a new campaign engine to faithfully replicate the look and feel of 21st century warfare. Extensive research into military planning and doctrine as well as consultation with experts in joint and coalition warfare from the United States, Britain, France, Sweden, Saudi Arabia, Russia, and several Pacific Rim nations, have resulted in a highly interactive, non-linear campaign engine that promises non-stop, exciting, and very realistic game play, every time you strap on a jet, walk into the War Room, or fly a sortie as an Airborne Warning & Control System (AWACS) commander. You, as a player, are taking part in a fully interactive, ongoing, dynamic air campaign that lasts anywhere from several hours to several days. Your inputs will effect the outcome of the campaign. Depending on how well you fly the F-22 and battle manage from the War Room and AWACS, your actions, in large measure, determine whether your side wins or loses the campaign.

The artificial intelligence (AI) portion of the campaign engine uses a strategic assessment process and methodology first adopted by U.S. and coalition forces in the Gulf War. Known as the "Five Rings" strategic assessment and campaign building process, each adversary is examined, targeted, and struck using a campaign template that identifies "centers of gravity," and the most cost effective way to force an enemy to yield to your will. Your adversary will be doing the same thing to you. He will react to your moves and send forces to destroy you and your ability to fight. From the war room you can use your intelligence assets to try and get an idea of what it is the enemy is going after and what kind of operations tempo he is trying to sustain in order to defeat you. Pay close attention to this. If the enemy is able to maintain high sortie rates against you in offensive operations, you may have to shift your effort to more defensive sorties in order to dull the effect of his campaign. Generally, it is always better to maintain a high rate of offensive sorties. Although defeat can be avoided through good defense, no war is ever won by it.

Five Rings Process

The Five Rings process is derived from the 1990-1991 work of USAF Colonel John A. Warden III and his followers during the build up and execution of the Gulf War. Col. Warden convinced Gulf War commander, Gen. Norman A. Schwarzkopf, of the need to adopt a radically different strategy and warfighting template for his battle with Iraq. Warden's basic premise was that all nation states consist of five concentric rings –or centers of gravity—the innermost ring being leadership, then key production, infrastructure, population, and—finally—fielded military forces. Prior to the ascendancy of air power, the only way to subdue a nation state was first to engage and then destroy the opponent's fielded military forces. Until that

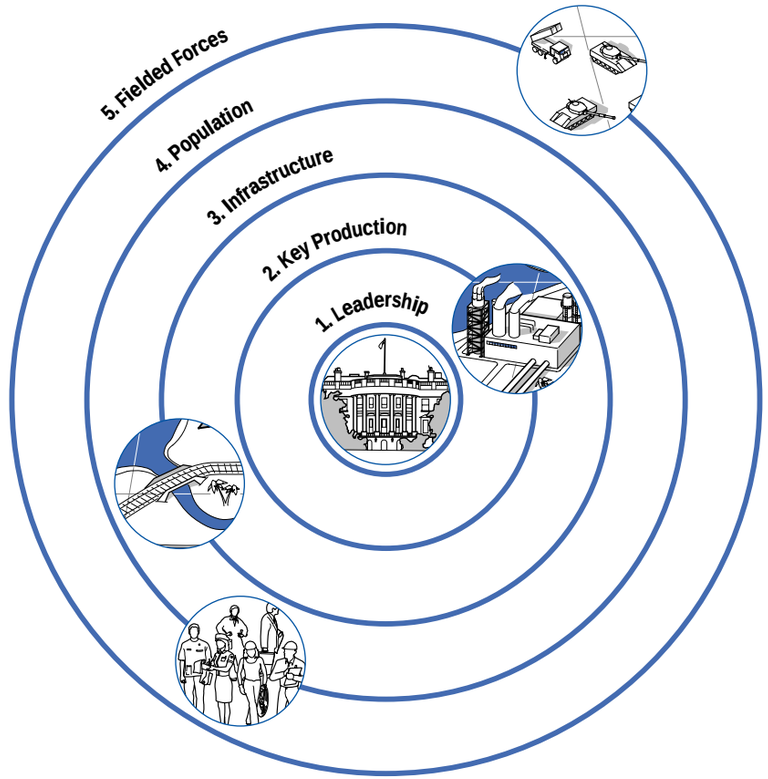
Campaign

was accomplished, the other centers of gravity (i.e. all other areas vital to the survival, continued functioning, and will of the nation state) would be impossible to reach. With air power, this is no longer the case. All aspects of a nation state are vulnerable to attack and destruction by air power from the onset of hostilities. Having said that, Warden and others believe that leadership is the real key to success or failure in war. When an enemy's leaders decide they had enough, they sue for peace—or someone takes power away from them. For that reason, every action in war should be geared to affecting the enemy's leadership directly or indirectly.

"A useful analogy that helps make the five rings process readily understandable is that of the human body compared to the modern nation state. As the president (or dictator) is to the nation state, so is the brain to the body. These are **leadership** centers of gravity. **Key production** centers of gravity, that is oil, gas, water, and electrical plants correlate to the human body's lungs, stomach, and circulatory system. All are energy conversion devices. **Infrastructure** in the nation state refers to the road, bridges, rail, and airways that link the country together. The human body analogy to this is muscle and bone. The nation state's people – the men, women and children that populate a nation state - correlate to the myriad of cells that make up the human body (**population**). The outermost ring of the nation state - **fielded forces**, the armies, navies, air forces, and police that protect and defend the state - relate directly to the human body's leukocytes that seek, attack, and destroy any threat to the body. An accompanying chart shows the five rings and relates then directly to nation state centers of gravity (CoG's) in an artists rendition. Note how the CoG's have multiple targets in each category, if you stop and think about it, this war-fighting principle embodied in TAW and the current doctrine of many modern air forces is nothing more that a logical extension of what most of us do when faced with a physical confrontation. Our first instinct is to avoid harm to ourselves and those around us we care about. The second instinct, if confrontation is unavoidable, is to convince our opponent to do what we want him to do at the lowest possible cost in physical injury and embarrassment to ourselves. If this can't be done, we use whatever force is necessary to convince our opponent to do what we want him to. The point is, regardless of whether we are punching our opponent in the nose, arms, or legs, our entire focus is on getting his leadership functions to do what we want. This then, is the essence of what you are trying to do in TAW."

Total Air War Campaign

Total Air War has adapted the Five Rings Process to allow for superb game play. Political targets (PIT) include multi-storied structures that house the government elite as well as temples and traditional government buildings. Key production (also known in some circles as "organic essentials" or "POL") targets include oil, gas, water, and electrical complexes, as well as power generating dams. Infrastructure targets (INF) are the roads, bridges, pipelines, railroads, and airports that crisscross the opposing countries. Industrial targets (IND) are the factories that turn out the war materials needed by the fielded forces to re-supply and fight. Command, control, communications and computing (C4) targets are the networks and nodes that send orders to the fielded forces and information back to the



Colonel J. A. Warden III's Five Ring Process

leadership. An integral part of the C4 nets are the radar and sensors that provide forces and leadership with "eyes and ears." Naval (NAV), Army (ARMY), and Air Force (AF) targets are also included in the TAW database.

Depending on the campaign you have chosen and the number of adversaries and allies in the conflict, chipping away at one or two of the five "rings" may be sufficient to achieve battlefield success. For example, attacking only infrastructure (roads, bridges, railroads, and airports) and key production (oil, gas, electricity, and water) targets may shut an opponent down and cause him to sue for peace. However, in large scale conflicts with competent adversaries, it is often necessary to create a parallel attack on the entire system to cause its collapse and surrender. An analogy might be useful here to understand what is meant by "parallel attack." Assume you and several of your friends are forced to fight a large bear with only spears for weapons. If each of you makes an independent attack on the bear it is likely you may wound him but only at great risk to yourself and with little chance of killing the bear. However, if all of you rush the bear at the same time, even if some of

Campaign

you miss, it is likely that the bear will collapse from his simultaneously inflicted wounds (none of which done independently would kill him) and lead to his immediate demise. This is parallel attack.

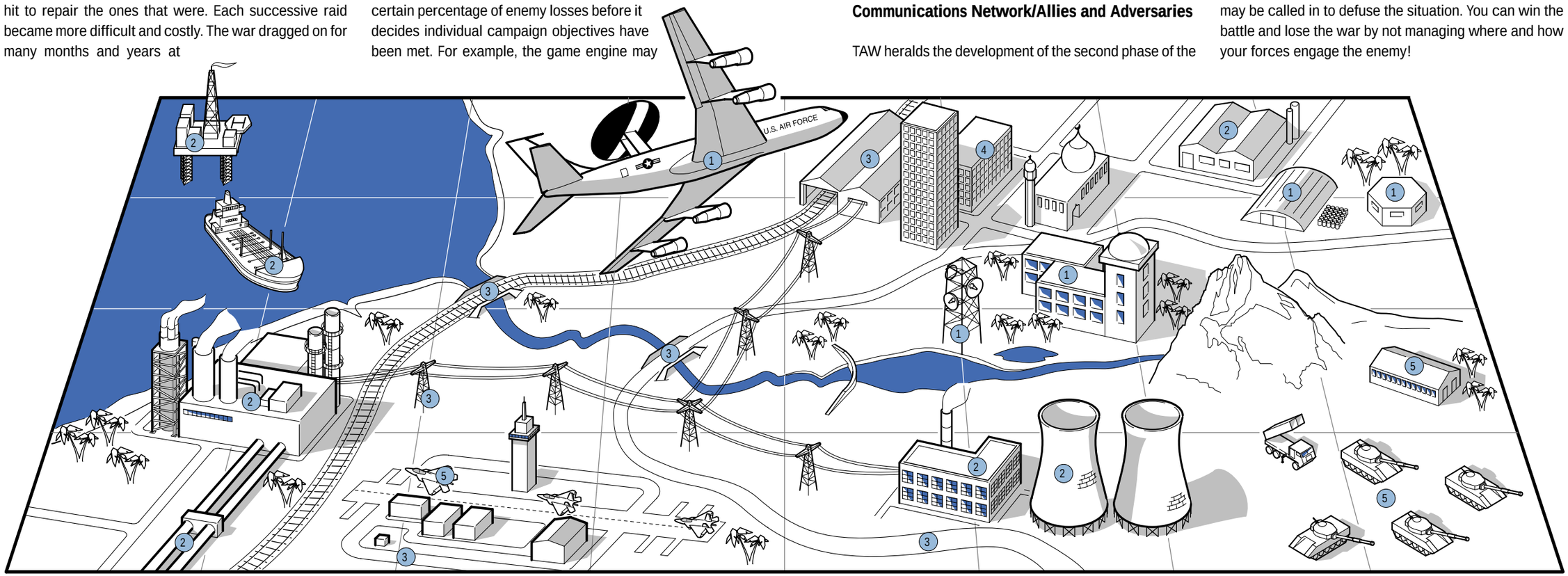
Prior to the creation of precision weapons, it was almost impossible to do parallel attacks. In World War II, it took almost 1000 B-17s to have a 90% probability of kill on a target that was as big as a soccer field. That meant exposing 10,000 airmen to danger and possible death for a single target kill. Consequently, raids were flown against target complexes in large areas or cities, one target at a time. The enemy learned from each attack and was able to divert resources from locations that weren't hit to repair the ones that were. Each successive raid became more difficult and costly. The war dragged on for many months and years at great cost in blood and treasure to both sides. Things changed dramatically with the advent of precision weapons. Less than fifty years after WWII, one F-117 carrying two, 2000 lb. bombs could accurately hit twice as many targets as those 1000 B-17s. As a result, in the first 24 hours of the Gulf War, more than 2000 targets across Iraq were put under attack at the same time. Iraq, like the bear in our analogy, simply went into shock and could not recover from this parallel attack. This is the effect of a modern air campaign on a nation state. Your challenge, as a player, is to inflict the same level of loss and confusion on your enemies.

It won't be easy. TAW's strategic game engine expects a certain percentage of enemy losses before it decides individual campaign objectives have been met. For example, the game engine may call for a 40% level of destruction on enemy infrastructure before it gives you the nod in that portion of the fight. To make matters even more challenging, the game engine demands you reach these objectives within a certain time frame. This reflects any modern commander's concern about world opinion and the political support he may or may not receive from his civilian leaders. Time is not your friend in this game. Like Schwarzkopf in the Gulf War, you need to worry about your government deciding the effort is not worth the cost, and sending you and your forces home before the job is done. It is political reality, and you have to deal with it!

Communications Network/Allies and Adversaries

TAW heralds the development of the second phase of the C4 network developed for F-22 ADF. In TAW, early warning radar (EWR) sites detect inbound enemy aircraft and uplink data to the airborne AWACS aircraft. Airbases augment this data flow further. Targeting a nation's C4 network will significantly affect their ability to wage war. A player must use his own system sensors to pay close attention to his borders.

The dynamic campaign engine may very well cause nations both in and out of the theater to be drawn into the conflict. Neutral nations whose territories have been overflown by careless combat patrols or bomber raids may decide to ally with a nation hostile to your own. Border skirmishes can quickly escalate and UN forces may be called in to defuse the situation. You can win the battle and lose the war by not managing where and how your forces engage the enemy!



Applying Col. Warden's Five Ring model in the target rich, Total Air War environment

1. Leadership **2.** Key Production **3.** Infrastructure **4.** Population **5.** Fielded Forces

Initiating a Campaign

Login

Initiating a Campaign

Login

When you first start TAW, you are prompted to enter your Pilot Name and Callsign. You can also choose a pilot photograph and squadron patch. These will appear in your pilot records throughout your pilot's TAW career. You have the option of adding your own patch and photograph to the Login screen in place of those included with TAW.

Personalize your campaign in the Login window

To add a user generated patch or pilot photo to TAW, both types of picture file must be in the .pcx file format, and be 96 X 96 pixels and 256 colors. If the file is a pilot picture, then place the .pcx file into the directory folder marked /Pilots (within the TAW directory, wherever you installed it). If it is a squadron patch picture, then place the file into the directory folder marked /insignia.

Campaign Selection

To begin a campaign in TAW, select the CAMPAIGN button on the main interface screen after you have confirmed your Login identity. This will take you to the Campaign Selection screen. From here you can choose to start or continue any of the ten available campaigns.

There are ten campaign scenarios in DID's Total Air War. They are listed on the left hand side of the Campaign Selection interface screen. You can scroll through the list and select on one campaign at a time. When a campaign is highlighted, the appropriate briefing will be displayed in Campaign Information window. If you are just starting you will not have enough experience to play every campaign scenario available. The advanced campaigns are reserved for players with more experience points because they are extremely challenging. Take your time and be patient, your effort spent in winning the less complicated campaigns will be rewarded with access to those more challenging campaign scenarios!

If you have already started a campaign and just wish to continue from where you left off, click on the appropriate scenario (it should have the word "ACTIVE" stamped across it) and then select the Continue button below the Scenario Selection window to resume play. When you select a campaign that you have begun but not yet completed, TAW will display two statistical summaries of your performance to date in that campaign scenario. One graph is your score graph and the other graph is your damage graph. However, should you wish to play the campaign again from the start, select New to launch the scenario afresh. You do not have to save your campaigns whenever you are finished playing, as TAW will do this automatically for you when you leave War Room and return to the main interface. The program will also automatically save your scenario for you once every hour of game time.

Select from ten truly dynamic campaigns

The Campaign Information window displays the specific information associated with each campaign. This information is displayed when the desired campaign is highlighted in the Campaign Selection window. Option buttons within the Campaign Information window include:

Map – displays campaign scenario "big picture" with color coded alliance markings. Green is allied, Red is enemy, and Blue is neutral. Note that these alliances are only accurate at the start of a campaign and may not represent the current conditions from a saved campaign.

Briefing – text information that outlines the current campaign scenario.

Pilot Log – displays your current pilot information, current ratings and score. This log is only updated on completion of a campaign, it will not update when a campaign is still active.

Campaign Log – shows information about all of your campaign successes, failures and ratings.

For detailed information about each scenario, please refer to the Scenarios section, found later in this manual.

War Room

War Room

Introduction

The War Room is the high-level strategic hub of Total Air War's campaign. From the War Room you can access The AWACS command station, the F-22 cockpit, or just watch the air battle unfold before you. The War Room also provides access to the information you need to build yourself the "big picture" as you implement your strategy.

The War Room is composed of five sections; the War Room display, the Mission Roster, the War Room Mode buttons, the Target Class selection buttons, and the War Room control buttons. Each of these sections will be discussed here to introduce you with their location and operation.

War Room Display

The War Room display is the large window located in the center of the screen. It is capable of depicting the current situation or user selectable campaign information. The bar across the top of the display is your campaign timer. It tracks current day (numerically from the start of hostilities), current game time (twenty four hour clock) and provides you with a count down timer until the campaign must be completed. By default, it displays the theater map.

Mission Roster

The mission roster is the small display window located in the upper right-hand side of the War Room screen. The roster displays the current campaign missions that you can choose to fly from the War Room if you press the "Fly" button at the bottom of the screen. The roster includes both AWACS and F-22 missions. Please note that these missions do not include the scramble missions, which are activated by pressing the "Scramble" button.

War Room Mode Buttons

The War Room display is capable of performing many different functions to aid you in assessing the current status of your campaign. What information appears in the main window is determined by selecting the desired Mode button. The Mode buttons are located from top to bottom on the left hand side of the War Room interface screen. The available Mode buttons are:

Theater: The default mode, this mode displays a map and available target data for all allied, enemy and neutral air and land forces which the player has selected.

Briefing: Will scroll through the current scenario briefing information. To stop scrolling the page simply place the mouse pointer over the display and click on the left mouse button, to continue the scroll, click again.

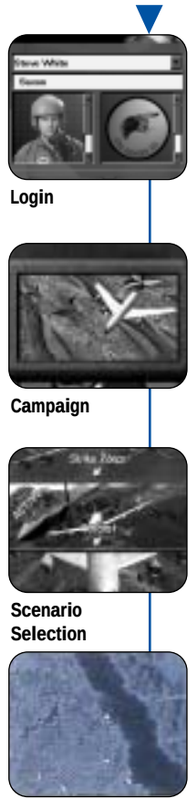
Watch the battle unfold in the War Room

Strategy: Displays an up to date indicator of the current allied strategy and how it is progressing alongside, if the data is available, an indication of which strategy intelligence suggests the enemy is pursuing.

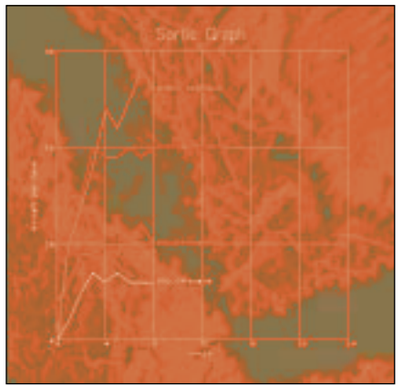
Target List: Displays the current strategic target list built by your war planners. The targets are displayed in order of strategic value, from highest to lowest. There is also a column for current percent damage and a column that shows the number of inbound strike aircraft assigned to destroy the target. To view a target location on the map, highlight the required target and hold down the left mouse button, to cancel release the button.

Event Log: The event log is an asset status list describing what is currently going on within the campaign.

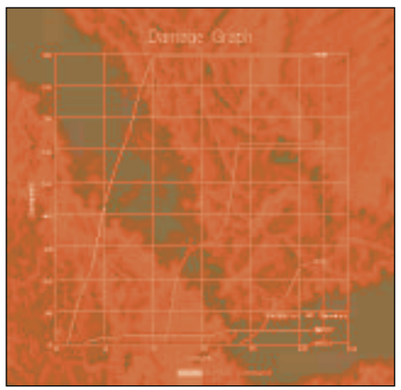
Damage: The damage map mode display depicts the current status of the selected target classes (selected from the right hand side of the map display) within the theater. Selecting the Allied or Enemy losses button below the target classes will highlight the areas where the aircraft losses are occurring. A brighter color (red for enemy, green for friendly) indicates a region where higher losses have occurred. You can also view the damage status of any target class in theater by selecting the desired target class button on the right side of the War Room screen. With a class button highlighted, all targets of that class will display on the campaign map. A green dot indicates that no damage has been sustained, orange some damage and red that the target has been destroyed.



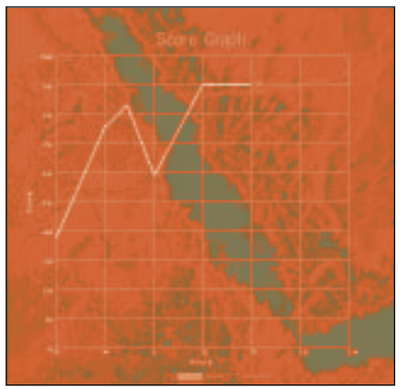
War Room



Sortie Graph: This graph indicates the number of sorties (one sortie equals a single aircraft taking off completing its mission and landing again) flown versus time during your campaign. In general you want to see friendly sorties above enemy sorties, this usually has a direct translation into higher operational tempo.



Damage Graph: This graph allows you see the damage sustained during the campaign for both allies (shown in green) and enemies (red). Use the target class buttons to the right of the display to view each category. Overall success for currently assigned target strategy for the campaign can be determined by looking to see if either of your performance lines intersect the required damage line on or before that same performance line reaches the time limit line. Highlight the Label button to the right of the display and a key will display at the foot of the damage graph, red indicates your performance whilst in an AWACS and blue whilst flying an F-22. A block will then display across the top of the graph to indicate which point of presence you have been using most during the campaign.



Score Graph: This graph shows your game score and thus indicates how well you performed your roles (F-22 pilot and AWACS commander) while playing the selected campaign scenario.

Scramble: Pressing the button turns it off and on, when set to on, "Scramble" will present the player with front line based F-22 intercept missions. You also have the option to turn the scramble missions down as they are presented to you.

Target Class Selection Buttons

The information displayed in the War Room is filtered by the array of filter buttons on the right-hand side of the War Room screen. Each of these buttons represents one of the following ten target classifications:

AC (aircraft)
ARMY (army targets)
NAV (naval targets)
POL (petrol, oil and lubricants type targets)
PIT (political targets)
GB (ground based vehicles and SAMs)
AF (air force targets)
C4 (command, control, communications and computing)
IND (industrial targets)
INF (infrastructure targets)

Selecting any of these filters allows you to view information about that class of target on the War Room Map display. For example, when viewing targets in Map mode, selecting only NAV will limit the display to solely Naval type targets. If you select GB, AF or C4, not only are the appropriate targets displayed but also the effective range of any radar at that target. If the filter button highlighted corresponds with the current campaign strategy, the top twenty targets of that class will be numbered in the map display.

Hint
The War Room remembers your filter preferences for each of the different War Room modes. For example, you may prefer to display only aircraft and ground based vehicles while using the map mode. But while in the damage mode you prefer to display just the infrastructure targets. As you jump between each of these two modes, the filter buttons will automatically reset themselves to their last position.

War Room Control Buttons

At the bottom of the War Room screen are the War Room Control buttons. There are three buttons labeled; Fly, Skip and Exit.

Fly: Pressing this button will take you to the mission selection screen where you can choose to fly any of the available F-22 missions or take control of the AWACS.

Skip: This button advances game time at a much faster rate.

Exit: The Exit button will exit the current campaign, save it and return you to the campaign selection screen.

War Room Overlays

In a number of War Room modes (in particular the Map and Damage modes) you can overlay additional information on top of the War Room map. For example, you can label allied and enemy flights and draw national borders on top of the map. You can also depict current international Allegiances, color coded by present orientation, Blue for neutral, Red for enemy and Green for forces that are friendly.

Hint
The amount of information you can overlay on flights depends on your knowledge of enemy movements. If your C4 network has detected and identifies an enemy flight, this will be reflected in the War Room. Allied missions and aircraft types are labeled.

War Room Graphs

The War Room graphs show both allied and enemy damage levels. Use the filter buttons to control which graphs are drawn into the main window. The graphs can be used to gauge player performance during the campaign. A steeply inclined line indicates the player is doing a good job of executing the campaign strategy and causing enemy systems to collapse and cease functioning. On the other hand, if the line shows only a moderate incline, this indicates that the player is not achieving the campaign objectives quickly enough, and could result in a stalemate or failure. A flat line is cause for serious alarm! You are losing the war!

War Room Damage

By default, the War Room shows you a real-time display of all armed forces in theater. If you switch the War Room into Damage Mode, you can get an indication of the distribution and level of damage throughout theater. Using the filter buttons, select which target class you would like to examine and each of the appropriate targets will appear in the main map window. A small indicator of the current damage level of each target appears adjacent to that target's icon. Allied and enemy aircraft losses are displayed by coloring areas of the theater where losses have occurred. The more dense the color, the greater then number of kills that have occurred in that area. You should anticipate to see these high-loss areas clustered around the borders between allied and enemy nations.

Hint

Knowledge of which areas are the most dangerous and are suffering the greatest losses is particularly useful to the AWACS commander. Re-direct strike flights to avoid the "hot-spots" where enemy defenses are proving most successful.

Advancing Time

The TAW scenarios vary in duration and some, if you play them in real-time, will have you living in front of your computer for almost two weeks! We appreciate that you might not want to wait that long to determine the outcome of all your hard work so we've included a Skip option which accelerates the rate at which the campaign progresses. If Skip is selected and you decide to enter either the AWACS or the F-22, then accelerated time will stop and progress will revert to real-time.

Points of Presence

The high-level strategic War Room is somewhat removed from the front-line where the air battle is being fought. Since there is nothing proactive to be done while in the War Room you will need to fly either an AWACS or an F-22 mission if you wish to affect the campaign. If you wish to leave the War Room and take the fight to the enemy, there are three routes for you to follow. *(Please refer to illustration on page 41)*

1. You can choose to fly a scramble mission and drop into the cockpit of an allied F-22 ready to engage in-bound bogies!

2. You can opt instead to fly one of the F-22 missions listed on an allied airbase roster and edit your mission with the TAW Mission Planner.

3. Or instead you can take on the role of the AWACS commander and direct the air war as it unfolds on your radar scopes!

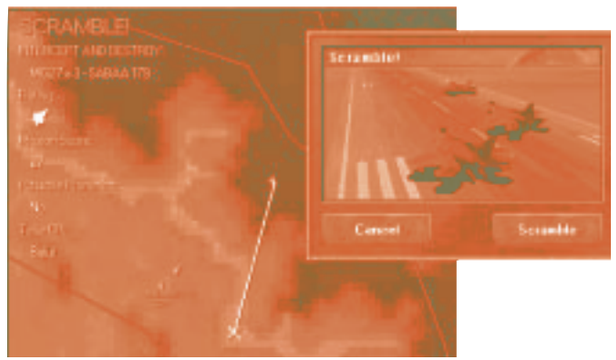
Scramble!

Introduction

On the left hand side of the War Room screen is the Scramble button. If this button is selected TAW will prompt you if a scramble mission comes up. A scramble mission is generated whenever an in-bound enemy flight is detected by an allied airbase. If you accept the scramble mission you will be given the opportunity to fly from the airbase and intercept the incoming bandits!

Scramble!

Airbases are constantly monitoring their airspace for enemy aircraft. Occasionally enemy flights will evade the CAP and SAM defenses and make their way into allied territory. When this occurs and when they are detected by an allied airbase's EWR, that airbase scrambles a pair of fighter aircraft to intercept. If you have chosen to accept the Scramble mission by pressing the Scramble button in the War Room, then when a scramble situation occurs the pop-up Scramble! window will appear in the War Room Interface.



Scramble! Scramble! Scramble!

In map mode, the War Room map will zoom to the airbase requesting the Scramble mission and highlight the inbound enemy flight. The complexity of the Scramble mission will depend on your pilot's ranking; new pilots will only be asked to intercept a single aircraft, but more experienced pilots may face up to three or four flights of aircraft!

If you Decline the Scramble mission then you will continue with your duties in the War Room. However, if you chose to accept the call to Scramble then you will be dropped into the cockpit of a fuelled and armed F-22 waiting at the end of the runway ready for take-off. Good luck!

Hint

Successful Scramble missions are one of the quickest ways to accelerate your way through the ranks. So if you want to improve the range of Player Missions you can fly, spend some time honing your fighter pilot skills by flying more Scramble missions.

Player Missions

Check the roster for deep strike missions

Player Missions

Introduction

Selecting Fly from the War Room window will launch you into the Player Mission Selection window. On the left hand side of the interface are listed all available F-22 and AWACS missions currently listed on rosters in allied airbases within theater. As each mission is selected, the waypoint and target information is displayed in the window adjacent the mission list.

Once you have selected an appropriate mission, if it is an F-22 mission you can either accept the mission as is and Take Off immediately, or Edit the campaign generated mission with the Mission Planner. If it is an AWACS mission you can accept and jump directly to the AWACS.

Mission Information

As you select each mission from the list, a briefing describing the mission, its objectives and the aircraft that are currently assigned to your flight, is displayed in the Mission Information window. Selecting the Map option, you can view the waypoint route overlaid on top of enemy SAM and EWR radar threat distances. Where appropriate, pressing the Target View will show you a real-time image of your objective.

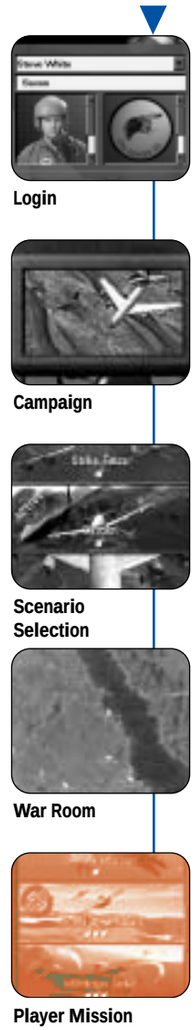
Ranking

Each mission is scored according to its complexity: Single F-22 missions such as escort missions will be flown far from the frontline; three F-22 missions such as interdiction missions will have you hopping over the border into enemy territory; and five F-22 missions such as an AWACS-kill, will see you operating deep into enemy territory without any friendly assistance.

While your rank is low, you will be denied access to many of the missions listed in the Mission Selection window. However, the more time you spend in the F-22 and the AWACS, and the more Scramble missions you complete, will improve your rank and grant you greater access to more missions.

Hint

Mission scoring in Total Air War is a complex process that rewards you if you keep both your plane and pilot (i.e. you) in one piece! It is better to limp your damaged F-22 back into allied territory than to eject behind enemy lines. Think carefully before you are tempted to destroy "just one more bandit" after completing your mission objective – if the gamble fails, your progress through the ranks will suffer accordingly.



AWACS - A Bird's eye view of the Allied offensive

AWACS – Campaign

Introduction

If there is an allied AWACS airborne, you can take on the role of AWACS commander. The AWACS provides the command and control platform vital for controlling all airborne allied aircraft in theater. In TAW, it's role is vital as it receives updates from the allied EWR network and J-STARS aircraft. Using information available through War Room intelligence, you can use the AWACS to coordinate all your allied aircraft and hasten the arrival of allied victory.

Tactical Advantage

Using the drag-and-drop command interface, vector allied flights to intercept inbound enemy aircraft. With your knowledge of where the most kills and losses are occurring you can move your CAP flights into more strategically important positions. Re-position your refuelers to top-off strike flights before they leave the safety of friendly airspace.

C4 Network

As long as your EWR network is in place, the AWACS will receive additional information from their remote sensors. This means that you should be able to identify aircraft and get a much clearer picture of the air war at much longer ranges. This will permit you the valuable time needed to re-direct intercept flights to get the job done.

Hint

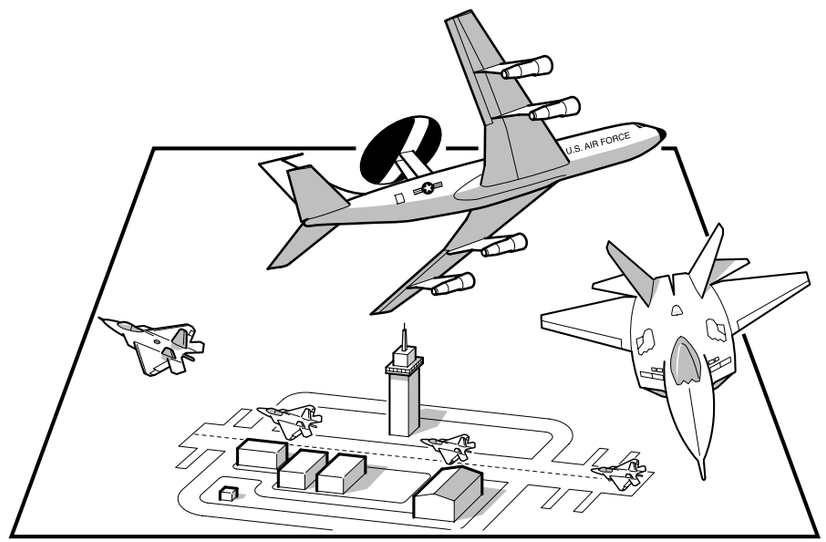
Seize the tactical advantage: the AWACS is a very valuable asset and you can be sure that your enemies will throw everything at it in order to drop it from the sky. If your EWR and C4 network are in place, keep the AWACS from straying too close to the front-line where it risks being shot down. However, if your communications channels have been degraded or possibly even destroyed, you'll have to let the AWACS fly forward in order to see the developing air battle. You must realize that moving your AWACS forward is quite a gamble!

Dropping into an F-22

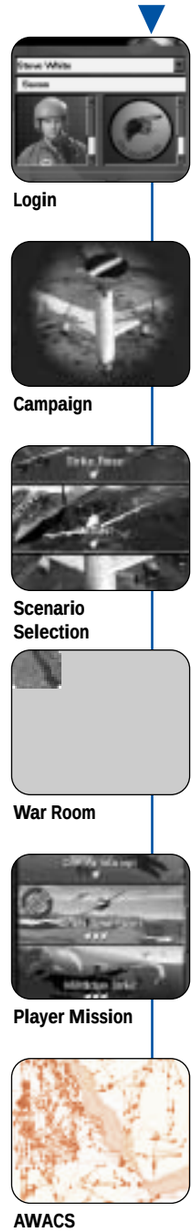
At any time during your AWACS session, you can leave the AWACS and drop into an allied F-22 by double-clicking the mouse on the F-22 icon. Immediately you will assume control of the F-22 and hand the AWACS to the computer controlled AI. If your F-22 aircraft gets destroyed or you eject, you will be thrown back into the AWACS again. Conversely, if the last Allied AWACS lands, or is destroyed, whilst you are piloting an F-22, you must remain inside that aircraft.

Hint

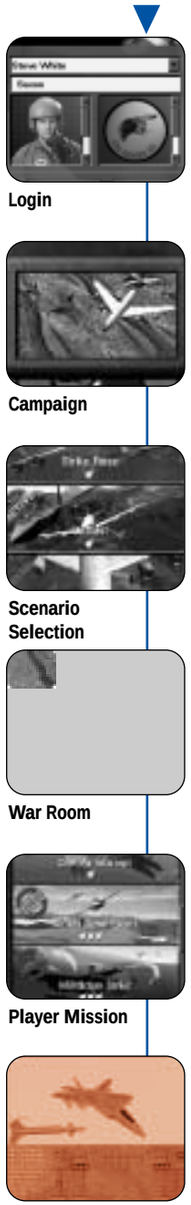
Avoid the temptation to risk your F-22 aircraft by flying gung-ho into every dogfight! The F-22 is the most advanced fighting machine in theater so its loss will be to the detriment of the allied forces.



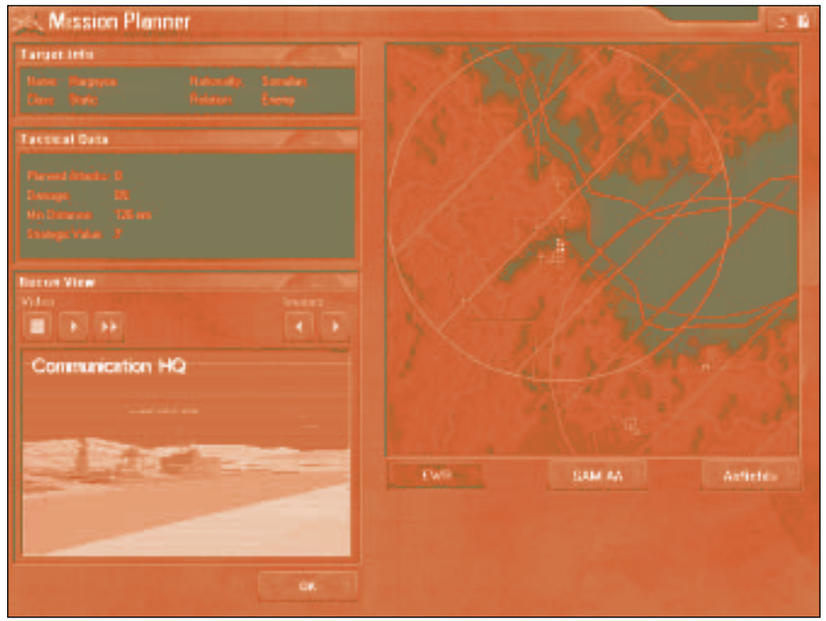
Total Air War, multiple point of presence warfare



Mission Planner



Hand edit your mission with the comprehensive mission planner



Choose and observe your targets in the target selection area

Mission Planner

Introduction

The Mission Planner is launched by selecting Edit from the Mission selection screen when an F-22 Mission is highlighted. Once invoked, the main Mission Planner interface lists six planning aspects of the missions that the player can edit: the target area; the mission make-up; the targets each strike aircraft will attack; the weapons each flight will carry; the route flown by each flight; and the attack pattern over the target.

Whether each of these components is available to the player is determined by the type of mission being edited. For example, there is no need to assign individual strike targets to a flight tasked to CAP and as such, this option will be grayed out when editing a CAP mission in the Mission Planner.

When each component of the mission planner is completed, a green check mark will appear alongside the appropriate button in the main Mission Planner interface. When there is a red cross, that component is incomplete and needs to be either custom edited or you must press the auto button to have the mission planner complete the planning for you. If there are any incomplete elements of the mission when the player attempts to accept the mission, a pop-up warning message will appear. All aspects of mission planning must be addressed in order to exit the mission planner and fly the mission.

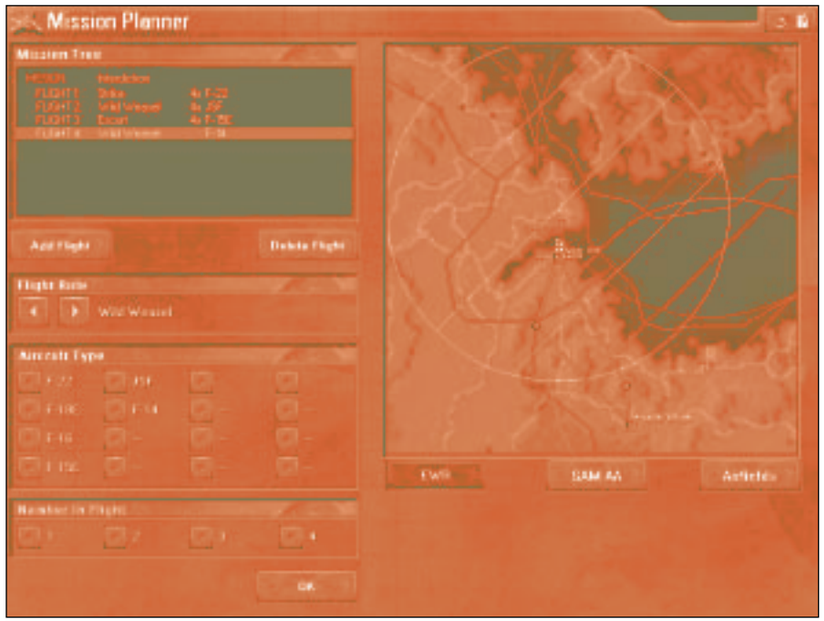
A summary of the mission make-up appears in the top-left of the screen in the Mission Summary while the accompanying map illustrates the position of SAM and EWR threats, the mission waypoint route and, when appropriate, targets. To zoom in on the map, press the SHIFT key while clicking and holding the left mouse button, dragging open a box over the area of interest. To zoom out, press the SHIFT key while pressing the right mouse button. To re-center the map, hold down the SHIFT key and left click the mouse cursor where you desire the map to be re-centered.

Hint

If you do not wish to edit any element of the mission, pressing Auto will make the Mission Planner AI complete that component for you. Also, at any time during the mission planning, exit the process and select Discard to return to the Player Mission selection screen.

Target Area

The Target Area selection screen allows you to view Intelligence pictures of your current target. It also allows you to select a different target for the current mission if you so desire. By default the mission planner is set to attack the Campaign generated target. However, should you want, you can refuse the Campaign target and select an alternate target. Each numbered target is a high value target, selected from the Allied “kill list”. Selecting and destroying a numbered taget will hasten the onset of victory. It is important to check the Strategic Value of the current target in the Tactical Data display to ensure that the target you selected is still



Assign Flights, select aircraft from available resources

valid under the current Campaign strategy. If allied intelligence is up to date, still imagery and live images from tactical recon sources of the target can be viewed in the Recon window.

Hint

The ability to select a different target than that assigned by the Campaign engine is a powerful feature of the Mission Planner. However, use it with caution because if you elect to strike a different target, you could be jeopardizing the outcome of the Campaign by not attacking a key component of the enemy force structure. Don't forget, the mission score will be recalculated if you elect to strike a different target.

Assign Flights

When the Campaign generates a mission, it checks to see which allied aircraft are available, and in what numbers, at the current airbase. It then matches suitable aircraft to the roles required in order for the mission to be carried out. Three flights are required to execute an interdiction mission: a strike flight, an escort flight and a wild weasel flight. If resources allow, a second escort or strike flight might be desirable.

If the player wishes to edit the flights assigned to the mission, select a flight in the Mission Summary and click Delete before adding a new one. Select which role you wish the flight to take and then select from the array of appropriate allied aircraft. Up to four aircraft can constitute a flight, however select EWR or SAM AA to keep an eye on the radar umbrella in the map window as the RCS of the mission varies. It is important to remember that a hand-edited mission must contain at least one flight of F-22 aircraft, and that flight's role must be the role determined for the player in that mission.

Hint

Each aircraft has a unique radar cross section (RCS). This determines how visible it is to both allied and enemy radar. RCS increases as weapons are added externally to an aircraft. This should be kept in mind when editing the composition of a flight for a mission. It is advantageous to select stealthy aircraft with internal weapons stores such as the JSF. However, if you choose to add external weapons and fuel tanks or add other flights which are not as stealthy, you risk increasing RCS to the point where the mission has a reduced chance of success.

Direct your wingmen to their targets

Assign Targets

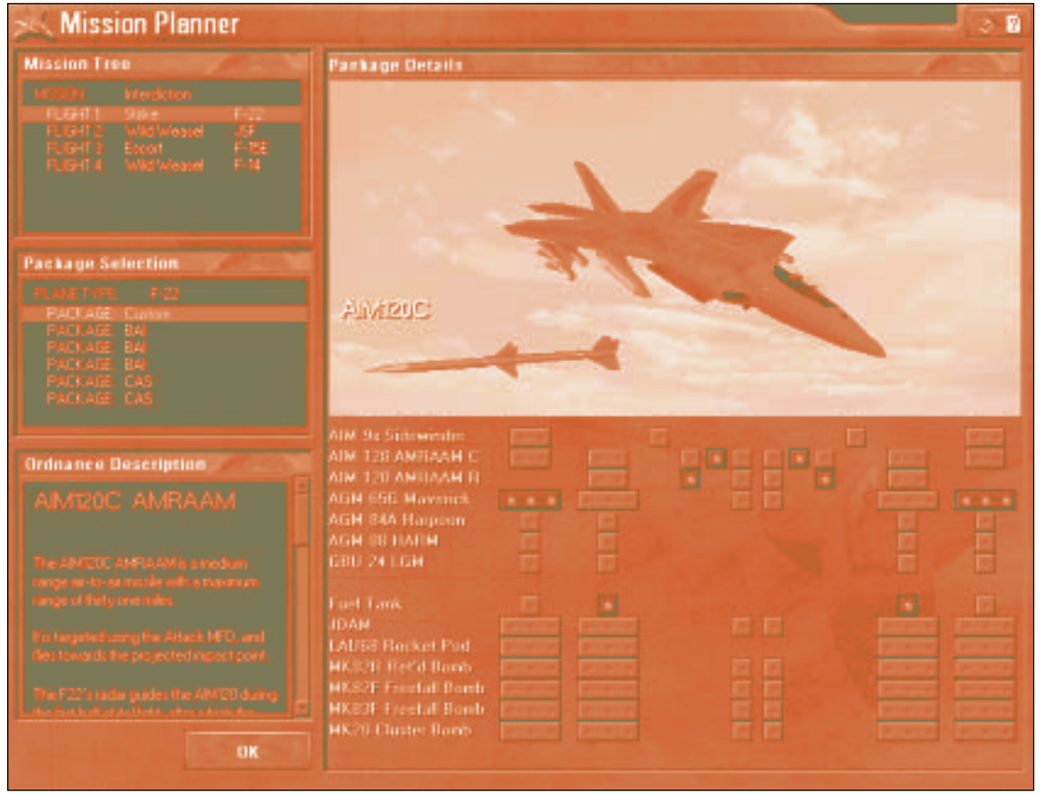
When flying strike missions, the Mission Planner allows you to assign different static targets to different wingmen in each strike flight. First select the appropriate strike flight from the Mission Summary window and then, using the mouse cursor to highlight each target, assign the highlighted target to the next aircraft in the current strike flight. Once again, the selected target is displayed in the Target View window if allied recon is operational and up to date.

Hint

Target selection is an important task and care should be taken in assigning targets to strike flights. Some targets have a higher strategic value than others, for example, destroying an airfield's control tower has a much greater affect on the operation of the enemy airbase than destroying an empty hanger. If you are not sure how to best assign targets, selecting Auto will make the Mission Planner AI automatically assign targets. Also, bear in mind that collateral damage can destroy targets that are closely packed together, so don't task your wingmen to strike targets near your own when a well placed cluster bomb will do the whole job alone.

Mission Planner

Choose your weapons...



Taking the role of an Armaments Officer

Weapons

The Weapons selection screen allows you to arm your own F-22 flight and those flights accompanying you on your mission. Select the appropriate flight from the Mission Summary and the aircraft will appear in the 3D View window. For anything other than the F-22, a selection of suitable weapon load-outs are displayed in the aircraft Package Selection window.

These contain a selection of weapons chosen for their suitability for the current mission type. Each weapons package is displayed below the aircraft in the Package Info window and also in position on the appropriate pylons in the 3D window.

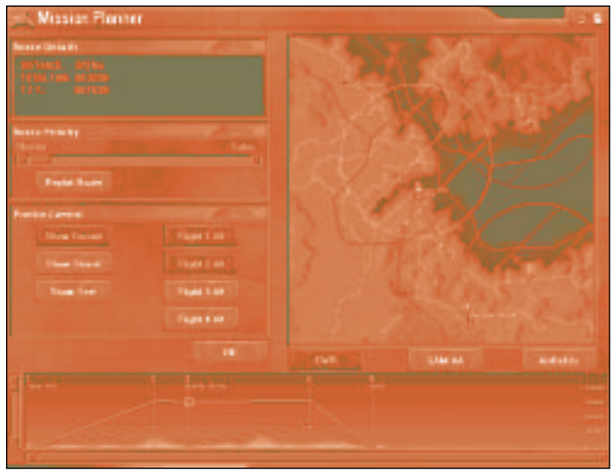
Hint

When selecting an appropriate package, you must remember the effect that carrying external weapons and fuel tanks will have on the flight's average RCS.

Selecting the weapons for the F-22 provides you with a lot more choice. Although you can choose from a number of pre-determined packages appropriate to the aircraft's current role, it is also possible to select individual weapons for each pylon. Weapons are selected by clicking the mouse cursor over the appropriate set of buttons in the weapons load-out interface below the F-22 in the 3D View window. Not all weapons are available in all pylon positions.

Hint

Customize your weapon selection to reflect those weapons you are most familiar with: if laser guided bombing is your forte, then opt for GBU-24; if you prefer to fly directly at the target with rockets blazing, then you should sling a LAU-68 rocket pod under each wing! Once again, don't forget that all important RCS when determining your loadout or you will lose the advantage of stealth as you head into combat and find it difficult to evade enemy forces with your increased drag and reduced maneuverability.



Use the Waypoint Editor to weave your way through EWR

Waypoint

When a mission is created, the Mission Planner AI attempts to find the most effective waypoint route for each of the flights in the mission. It takes into consideration terrain features (such as valleys), the position of EWR and SAM sites, current international borders and international allegiances, and the range of the aircraft in each flight. Although you can choose to accept the AI generated route, you can also Customize the waypoint route for yourself with the Waypoint Editor component of the Mission Planner.

The current waypoint is plotted in the map window. You can move the position of each waypoint by clicking the mouse on a waypoint number and dragging it to a new position. Clicking on the small yellow crosses mid-way along each leg of the waypoint route introduces a new waypoint between the numbered waypoint which comprise the leg. This too can then be moved into a new position. Waypoints can be removed by right-clicking the mouse on the appropriate waypoint number.

Automatic waypoint route generation is possible by clicking the Replot Route button in the Route Priority window. Dragging the slider bar between shorter and safer will vary the degree to which the Mission Planning AI priorities avoiding enemy forces and minimising mission duration.

The Profile window at the bottom of the Mission Planner interface illustrates a side view of the current route. It is possible to set the altitude at which flights pass each waypoint. Clicking with the left mouse button on a waypoint will allow you to adjust the altitude. The assigned altitude can be increased by dragging it higher or decreased by dragging it lower, as appropriate. If you click with the right mouse button, the whole waypoint route can be dragged to a different altitude.

Hint

If resources allow, a well structured Interdiction Mission should include an escort flight, wild-weasel flight and a strike flight. Each of these should arrive at the target at a different altitude: the strike flight low to avoid detection, the escort flight should stay high to provide cover for the strike flight and the wild-weasel higher still so it can light-up and destroy any SAM defences it encounters well before they threaten the strike flight.

Mission Planner

Attack Pattern

With the waypoint route complete, the final component of the mission to be edited is the attack pattern flown by each aircraft over the target. The Attack Pattern editor allows you to manipulate the actual flight path of each attack pattern through the target area.

For example, wild-weasel flights might want to fly a criss-cross pattern searching for SAM and AAA. By clicking the mouse on one of the legs of the pattern, it can be repositioned to provide better cover from hostile ground attack.

Attack patterns flown by strike flights vary according to the weapon they are using: guided-weapons are delivered by flying a dog-leg strike pattern while free-fall weapons must be dropped by over-flying the target.

Once again, select Auto to force the Mission Planner AI to complete the process for you.

Hint

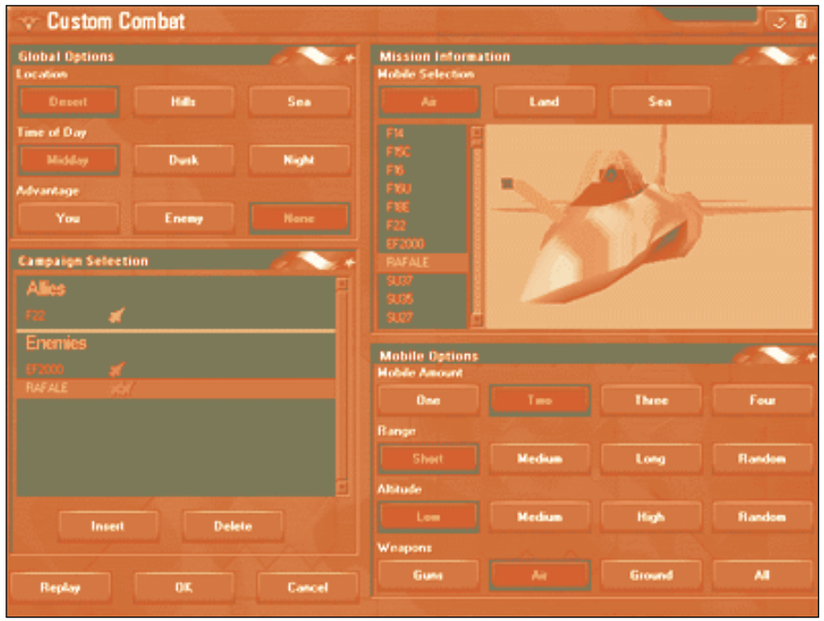
Your approach angle to the target can be changed by altering the IP waypoint in the waypoint editor. Avoid overflying towns, cities, bases and other built-up areas. SAMs and AAA are more likely to be positioned in these locations.

Summary

Now the mission planning is complete, select OK to jump into the cockpit of your F-22 and embark upon your hand-editted mission. Selecting Discard will return you to the Mission Selection screen and reset the mission to its original settings.

Dodge the AAA as you strike your target

Custom Combat



Hand edit instant combat action in Custom Combat

Custom Combat

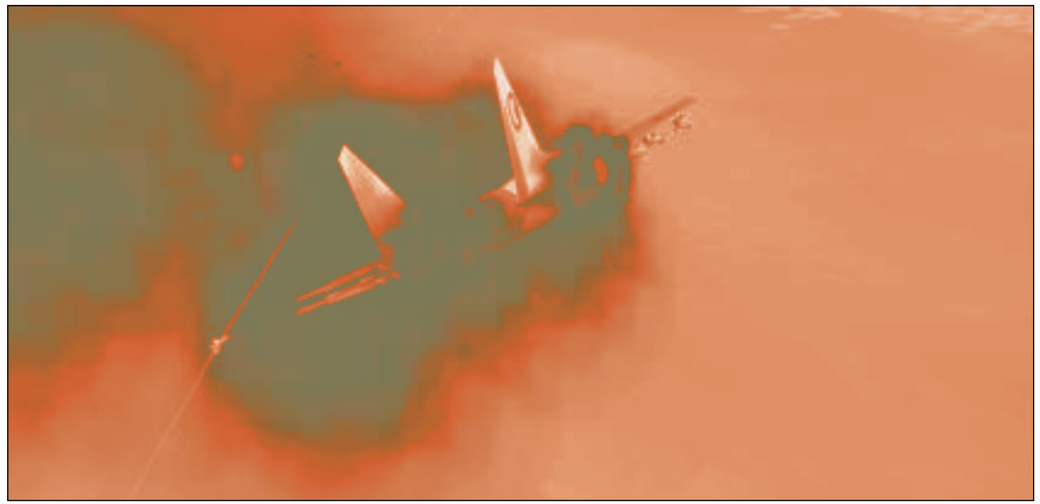
Introduction

TAW has a new module called Custom Combat. This module allows you to set up a Basic Fighter Maneuvers (BFM) engagement with any of the aircraft and vehicles available in TAW. It can also be played multiplayer to let you and your wingmen fly in a dogfight of your choosing. Select the Custom Combat tab from the main menu to launch the TAW custom combat editor.

Set the Scene

Using the Custom Combat editor, you can control what your BFM mission will be like. These options can be selected in any order you desire. The environmental conditions available allow you to choose the time and location of your mission. From the Global Options section of the interface select your desired Location (Desert, Hills, or Sea) and Time of Day (Midday, Dusk, or Night).

Using the Advantage selection buttons you can opt to give your flight the benefit of starting the engagement in a good position - behind the enemy. If you desire, you can choose that no side should have the advantage at the start and this will result in you confronting your foe head on. You can also give the advantage to the enemy, which will place them behind your flight. Keep in mind that these settings only apply to the start and after the mission begins it is up to and your wingmen to determine the final outcome of the fight!



Choose your adversaries in Custom Combat

Add Enemy Forces

A summary of your current mission can be viewed in the Formation Selection window. In this window you will see the results of any Insert or Delete actions you have performed. All aircraft and vehicles that are currently in your mission will be displayed here.

To add an aircraft, select the Air button from the Mission Information section of the interface. With Air selected, all available aircraft will be listed in the scrolling window labeled Mobile Type. Use the scroll bar to view your choices and make your selection by clicking on the aircraft's name. With any of the available vehicles selected (Air, Land or Sea), its 3D image will appear in the viewing window next to the scroll list. The 3D image can be re-oriented by using the left mouse button, the 3D image can be re-sized by using the right mouse button. After a suitable aircraft type has been selected, determine how many you want in the flight, and then the type of weapons you desire the enemy aircraft to have.

You can add any amount of enemies up to a maximum of nine flights (aircraft) or groups of ground-based vehicles, SAM, AAA and ships to your mission. Note that if you accidentally add a land-based vehicle to a sea-based mission, (or visa-versa) a pop-up warning window will alert you to the fact that the mismatched enemy equipment will not appear.

Take-off

Once you are satisfied with your mission, accept it and you will be propelled into the cockpit ready to fight against your chosen adversaries. On completion of the mission, you will be debriefed on your performance before returning to the Custom Combat screen once again. You can Replay the mission as is or make minor modifications and fly the mission over again.

Scenarios

Scenarios

Introduction

The Campaign scenarios available in TAW are very diverse in nature. They range from border conflicts to multi-national regional war. The TAW campaign engine has the ability to introduce and dissolve new international alliances – during gameplay. Thus the allied and enemy balance of power has the ability to change, literally overnight. Once you think that you have successfully attained air superiority – the picture may change, sometimes for the worse!

Regional Background

The Red Sea theater is composed of the countries within the geographic region surrounding the Red Sea and the Gulf of Aden. The countries located in the region are Egypt, Sudan, Eritrea, Ethiopia, Djibouti, Somalia, Yemen, and Saudi Arabia. The other nations with interests in the area include the U.S.A., Great Britain, China, France, and Russia.

Pre-1999 History

In the mid-1990s, most of the military might in the Red Sea region was found in only three countries; Yemen, Saudi Arabia and Egypt. All of the other nations, dealing with constant internal pressures and sporadic social unrest could ill afford any concentrated efforts at modern militarization. So the rest of the area's nations would bide their time and wait for their opportunity to field a national army that could stand against the might of any one of the "big three." Although there weren't any formal declarations of war within the region, there were also no real alliances. Each nation was kept busy dealing with internal problems of various sorts, so much so that any external issues were usually left unresolved. Border disputes erupted from time to time and were usually settled as a result of some form of military stalemate with each side claiming to be the victor.

Cultural Differences

Another factor within the region stemmed from the major cultural and religious differences between the peoples of the Red Sea area nations. The population in the southwestern part of the region was largely agrarian. Trading mostly foodstuffs and other essentials for survival, farming groups clustered into tribes and lay claim to several hundred acres of land. When arguments arose between neighboring tribes, the result was often bloodshed, as tribal land holdings sometimes crossed international borders.

Cities and towns within the region were often defined by the religious beliefs of the residents. Rarely, were there populations of mixed beliefs. Only the largest trading and commerce centers could tolerate such religious diversity. Religious beliefs also played a major role in state and national rule, often affecting the decision making and negotiating thought processes of the country.

Tensions

With all of the diverse people and religious beliefs within the area, tension was an everyday side effect. Although no formal declarations of war had occured in the recent past, that did not mean that nations haven't fostered ill will towards each other. Outright hostilities had not developed in the past because of the lack of either a credible military force or the capital required to support it. As a nation in the Red Sea area, you were either a "have" or a "have not" in the national forces department. But all of that was soon to change.

Current Situation

New fortunes, created by the discovery of precious metals and oil reserves within the Red Sea operations area have lead to regional unrest. International power struggles for the control of these precious natural resources now bolster nationalism and strengthen each countries desire to fight. With the new regional income, formerly poor countries now can afford to train and equip national military forces. All armed forces within the region are ready and willing to test their newly purchased hardware. It is a very dangerous time.

Rapid Economic Growth

While on an international antiquities excavation in southern Sudan, a professor and his archaeological team discovered unexpected oil reserves within that region. The oil deposits extended from within southern Sudan well into northern Ethiopia. Sudan and Ethiopia exploited the oil reserves and grew rich, becoming members of OPEC. The excitement over the discovery of new oil fields gave rise to new searches throughout the area for other oil reserves.

Another series of large oil deposits were found in the coastal region of Eritrea, Djibouti and Somalia. Although not quite as expansive as the fields discovered in Sudan, it was sufficient to provide these three nations with a 11% control over the world's petroleum market.

As the oil reserves along the Somali coast were being mapped out, researchers stumbled upon new gold deposits. As the initial gold strikes were quickly exploited, more were found. There were some days when the coastal nations ceased to function because almost every citizen was out with a pickax and shovel, looking for their share of the fortune. The nations of Somalia, Djibouti and Eritrea became wealthy practically overnight.

New Force Structures

Once the nations in the area possessed sufficient economic means, they quickly began to build their national forces. A massive new arms market developed in response to this demand. Foreign consultants were hired to advise the nations on hardware purchases. The result was a quite diverse range of equipment in use for each country, in some cases Russian built systems being used right along side western built systems.

Infrastructure

To support the new military, the old infrastructure which had supported the former way of life had to be updated. Airfields had to be modernized to allow strategic and tactical aircraft operations. A large anti-aircraft network had to be established to provide warning and protection from invading hostile aircraft. National landmarks and governmental assets had to be protected from attack and reinforced to help repel any air

strikes that might get through. Across all of the Red Sea theater area, nations prepared themselves for any outbreak of hostilities.

General Hints for Scenario Gameplay

TAW utilizes a dynamic campaign engine to create the situation that the player must react to. As such, hints to help you improve your score will be more generic in nature than with simulations which rely on scripted missions. Since conditions can vary dramatically, even when playing the same scenario a second time, it is wise to look for clues as to "how" the enemy fights, rather than memorizing what you see the enemy do the first time through. The next time it will be very different.

Intelligence Reports

As in the real world, intelligence reporting is part science and part art. Some of the reports you receive will be accurate and some will not. Use intelligence reports as a first estimate as to the enemies actual intentions and then try to confirm the enemies actions by paying attention to what the enemy is destroying. Also be aware that the enemy, like you, can change their classes of targets in response to the current status of the conflict. Just like in actual war, "stuff changes!"

Alliance Changes

You will discover that during gameplay international alliances can and will change. Be cautious of this and be prepared to "flex" and begin your fight all over again. When alliances change, air assets and C4 nodes will change to reflect the new situation. Front line bases will now be home to fighter and strike aircraft, whereas the more remote bases will now have the high value assets and other important strategic aircraft located there.

Scenario 1: OPERATION HIGHLAND

Background

Sudan is a country divided by religion. In the north, controlling the government and the air force are the followers of Islam. In the southern Sudanese highlands there is a loose conglomeration of Christians and Animists. Following Sudan's rise in power this stratification further increased national tensions. The Sudanese government then decided to end all the strife and began trying to irradicate the "Christian scourge." A mass exodus of people ensued, with several thousand people fleeing into Ethiopia and Eritrea. The United Nations was quick to condemn Sudan's actions, but the Arab state continued its religious "cleansing." Eritrea and Ethiopia finally issued Sudan an ultimatum, stop the violence or face the consequences.

The United States, in the name of humanitarian causes, aligned with Ethiopia and Eritrea to help compel Sudan to end it's Christian persecution. Forces on both sides of the battle line began preparing for the upcoming conflict. In a rapid move, surprising the United States state department, Sudan declared war on its southern and eastern neighbors and their allies; Ethiopia, Eritrea and the U.S.

Force List

Enemy Nations: Sudan.
Friendly Nations: USA, Ethiopia, Eritrea.

Objectives

OPERATION HIGHLAND is a response to a war declaration by Sudan. Your objectives are to reduce Sudan's capability to conduct an extended war campaign against Ethiopia and Eritrea. You must begin by degrading the Sudanese Command and Control (C4) system. After destroying the early warning and GCI networks, you must then reduce their air-to-air and air-to-ground capability by targeting Sudanese Air Force units.

Possible Alternatives

If you are successful in reducing their Air Force's strength, then you might be called upon to attack their land forces and try to prevent Sudanese land forces from crossing the southeastern border and attacking friendly ground forces.

Enemy Interests

Intelligence reports that Sudan has boasted about the strength of their Air Force in the international community. They will most likely attempt to prove this as they enter into a conflict. Other reports
indicate that Sudan will probably try to attack Ethiopian and Eritrean resource producing
infrastructure nodes. Be wary of this and be committed to protecting against any air attacks on
friendly centers of industry. If provoked by a sense that they might be losing the war, Sudan may resort to attacking targets that may have more of an impact on Ethiopian and Eritrean public opinion, such as churches, schools and universities, and government meeting places.

Scenario 2: OPERATION PORT OF CALL

Background

Yemen has always exercised control over the southern portion of the Red Sea. But as Eritrea has grown into a regional power, they have begun to compete directly with Yemen's authority. In order to secure a higher throughput of oil to the world, Eritrea began to make their own rules with respect to the south Red Sea straits. Yemen protested and some heated exchanges occurred between the two countries at the UN negotiating table. Finally it was Eritrea which broke from the truce talks, labeling Yemen as being totally unreasonable. After a two-week cooling period the talks began again. Once more the negotiations stopped, this time with Yemen leaving the table vowing to never return. They also added that any problems they might have in the future with Eritrea would be settled by force.

Russia, eager to gain regional support and much needed petroleum supplies aligned with Yemen and the two countries signed a joint force agreement. Yemen, now thinking that Eritrea would be foolish to engage a superpower, began actively enforcing their naval regulations in the southern Red Sea. The U.S. was caught off guard by the force treaty and began to align itself with Eritrea. In a bold move, Eritrea openly defied Yemen's authority and sailed a large oil convoy through Yemen territorial waters. Yemen was outraged, and the next time the Eritreans tried such a stunt, they would be punished. As the next large convey left port in Eritrea, the Yemen Air Force struck. They destroyed three Eritrean warships and five super tankers. Eritrea declared war on Yemen in response to their senseless disregard of Eritrean sovereignty.

Force List

Enemy Nations: Yemen, Russia.
Friendly Nations: Eritrea, USA.

Objectives

The key to the Yemen armed forces is their Command and Control structure, so your first task will be to attack C4 targets. After degrading the ability of the Yemen Air Force to see and react to you, go directly after their air-to-air and air-to-ground assets. By destroying Yemenis and Russian aircraft you will reduce their potential for any further devastating attacks on Eritrea.

Possible Alternatives

If Yemen refuses to capitulate you may have to reduce their potential for sustaining a prolonged conflict by destroying key nodes within Yemen's infrastructure.

Enemy Interests

Initially, Yemen's most likely course of action will be to continue in their effort to remove Eritrea's naval presence from the southern Red Sea area. Protection around key port facilities have been reinforced in anticipation of this, but in the short time since hostilities began not enough has been done. Friendly forces are relying on defensive air-to-air missions to keep the enemies strike aircraft at bay.

Scenario 3: OPERATION STRIKE FORCE

Background

Somalia's current ruling party has spent considerable effort in trying to develop nuclear weapons technology with the aid of China. To date, none of the work has paid off but a plant that was theorized to be capable of manufacturing weapon's grade plutonium was discovered by Ethiopian spies. In a quick, precision air strike, Djibouti and French aircraft leveled the research buildings to the ground. Incensed by this act of "outright aggression" against them, Somalia moved their weapon research to multiple, remote, clandestine locations. The Somali leadership vowed to continue research and to repay the aggressors for their unwarranted intervention.

The world watched as the nuclear research standoff continued. Djibouti and France both decided that the only course of action left was to strike all suspected research facilities in an attempt to put an end to Somalia's quest to become a nuclear power.

Force List

Enemy Nations: Somalia, China.
Friendly Nations: Djibouti, France, USA.

Objectives

You will be tasked with destroying the suspected industry sites that might be part of the Somali nuclear weapons research effort. Do your best to get your strike aircraft through to their targets. If the intelligence community still believes that a threat of nuclear research capability exists after disabling the industrial sites you may be called upon to hit other classes of targets.

Possible Alternatives

To enhance the chances of your strike aircraft getting their missions completed you may consider using dedicated SEAD missions along with your air-to-ground sorties. Some of your targets will be heavily defended.

Enemy Interests

The enemy will do everything they can to resist your efforts to invade their airspace and bomb their factories. SAM crews and C4 nodes will be watching closely for any suspect activity. Strike aircraft should expect to meet with a well coordinated resistance.

Scenario 4: OPERATION OUTCAST

Background

Saudi Arabia had long been one of the wealthiest nations in the Red Sea operations area. Almost all of Saudi's riches are the result of the country's control over the world's oil market. When Sudan entered OPEC and began to sell their oil to other countries, expectedly, Saudi lost a small portion of their consumer base. Initially the impact was negligible but in an attempt to fund a rapidly growing arms race, Sudan began "dumping" their oil into the world market at ridiculously low prices. Saudi Arabia tried to bargain with Sudan through OPEC mediation groups, but Sudan was still secretly using their oil to procure military hardware.

In desperation Saudi Arabia expelled Sudan from OPEC and attempted to impose economic sanctions on their former Northeast African ally. In agreement with Saudi Arabia, the United States and the United Kingdom also entered into economic sanctions against Sudan. But Egypt and France were quick to come to Sudan's aid, agreeing that Saudi Arabia had acted without the full concurrence of OPEC. Sudan demanded to be let back into OPEC and to be permitted to sell their oil on the international market. Saudi Arabia refused to re-admit Sudan to OPEC and denied their request for access to the world's oil market. Sudan, angry over the loss of revenue and the impact of the recent economic sanctions decided to settle their dispute with Saudi Arabia through the use of force. Sudan's foreign minister proclaimed, "If they won't listen to the pleas of an Arab brother, then let them hear the deafening thunder of our military might!"

Force List

Enemy Nations: Sudan, France.
Friendly Nations: USA, United Kingdom, Saudi Arabia.

Objectives

Initial intelligence estimates of Sudan's offensive capabilities indicate that they are well trained and quite able to inflict extensive damage on Saudi Arabia. Sudan is also receiving support from France in the way of aircraft, weapons military advisors and aircrews. Your first priority will be to attack their combined air force assets and attempt to reduce their offensive air power. From there you can expect to target C4 as you try to "roll back" Sudan's air defenses.

Possible Alternatives

After degrading Sudan's air defenses the Saudi War Council has determined that the allied aircraft will then go after Sudan's petroleum industry, in an attempt to reduce their oil output, thus trying to curtail the influx of additional arms and military hardware. You should also be careful of Sudan's strong ties with other Arab nations in the region. Secret alliances may end up having an effect on your war plans.

Enemy Interests

Sudan will mount a solid defense to your attacks, and they will probably try to target your airborne resources as best they can. Their only option at winning is to destroy your air force and make any victory you might attain a costly one.

Scenario 5: OPERATION FLAME OUT

Background

Djibouti and Eritrea share a large oil deposit that spans the border between the two countries. Rather than sharing the resource, each country laid claim to total ownership of the oil. A heated debate ensued as each country fought viciously to gain the selling rights to the oil. The UN intervened and was finally able to get both nations to agree to a "settling period" of twelve months. This settling period was a set amount of time that neither country could take advantage of the oil resources, while the field was researched and documented. It was also hoped that during this settling period, both nations would be able to develop a mutually satisfactory accord on the joint exploitation of the disputed oil resources.

Two weeks into the "settling period" Eritrean commandos conducted a raid on southern Djibouti. They succeeded in destroying a major petroleum production plant and storage facility in eastern Djibouti. This act of terrorism re-focused the world's attention on the region. As a result the USA discovered, through the use of satellite imagery, Eritrea's ulterior motive.

Eritrea is currently massing infantry, armor and artillery units in what is theorized to be a pending invasion of Djibouti. Intelligence also reports the presence of Russian units in the buildup. Although there is no movement visible as of yet, rumors are that Ethiopia has issued a nationwide force mobilization order.

Force List

Enemy Nations: Eritrea, Russia.
Friendly Nations: Djibouti, USA.

Objectives

If Eritrea has enough time to assemble and mass it's ground forces, Djibouti will be quickly overrun. The allied planners are tasking you to destroy Eritrea's petroleum manufacturing and storage facilities in an effort to immobilize the enemy ground force's vehicles before they can attack.

Possible Alternatives

You may also be required to directly target ground units themselves in an effort to ebb Eritrea's impending invasion south.

Enemy Interests

The enemy will protect their ground units and fuel reserves from your attack. They will probably also try to launch an anti-air offensive in an attempt to gain local air superiority. With control of the air, the enemy will be free to move their ground forces at will.

Scenario 6: OPERATION CHOKE POINT

Background

As a result of the large oil field discoveries, Sudan's petroleum output increased to rival that of Arab coalition partner, Saudi Arabia. Both countries relied heavily on Red Sea shipping lanes to move their oil products to their consumer nations. When Eritrea began to produce oil, they also used the southern Red Sea for shipping throughput. With all this traffic in the water, the number of shipping accidents began to rise. It was obvious that someone had to get control of the situation and regulate the shipping traffic. Eritrea and Yemen signed a trade waters agreement in which those two countries would provide regulation and control of ship passage through the southern Red Sea into the Gulf of Aden. Once Yemen and Eritrea seized control, the price of safe passage dramatically increased. Sudan and Saudi Arabia protested the toll fees. The argument hit fever pitch when Eritrea and Yemen decided to limit the number of Sudanese and Saudi tankers passing through the straits. This action had a severe impact on Sudanese and Saudi oil deliveries. As the situation now stood, Eritrea and Yemen had almost complete control over south Red Sea oil distribution.

Ethiopia, in an attempt to further its own causes, aligned with Eritrea and Yemen and was able to use south Red Sea shipping lanes at will. China, one of the largest consumers of the Red Sea oil products aligned itself with Eritrea and Yemen to avoid loosing its precious oil supply. Ethiopia, Eritrea and Yemen surpassed Saudi and Sudan in oil distribution revenues.

Sudan was in a difficult position. They were hurt the most by the developments in the south Red Sea. Saudi Arabia, because of their close ties with Egypt, was able to use the Suez Canal (although at considerable cost) to get it's oil shipments out. Sudan did not have the luxury of using the Suez Canal because of a long standing border dispute with Egypt. Their only option was to use the Red Sea.

While Eritrea, Ethiopia and Yemen asserted control over the shipping lanes, they also began building the strength of their armies. Nationwide military conscription was instituted to start filling the ranks. Foreign advisors and personnel were brought in from China to assist in reorganization and training of army units. The extra capital brought in by the increased oil sales was directly used to amass military hardware. It certainly seemed as if Yemen, Eritrea and Ethiopia were preparing to declare themselves the "newest" regional powers.

As a final step to gain control over the oil distribution, Yemen and Eritrea closed the south Red Sea to all Sudanese and Saudi Arabian oil tankers. Sudan's rebuttal came in the form of a war declaration on Yemen, Eritrea and Ethiopia. Saudi Arabia, entered a non-binding use of force agreement along with Sudan against the antagonistic nations that had closed the southern shipping lanes. The final line had been crossed.

Force List

Enemy Nations: Yemen, Eritrea, Ethiopia, China.
Friendly Nations: USA, France, United Kingdom, Saudi Arabia, Sudan.

Objectives

Your first targets will consist of ground based military units in an attempt to minimize the chances of an enemy ground offensive. Any subsequent target lists will be linked to the main objective of precluding any coherent ground based attacks by destroying key industrial, infrastructure, or fuel producing targets.

Possible Alternatives

As the enemies military buildup continues you may have to destroy other classes of targets in an attempt to reduce any military advantage the enemy might have.

Enemy Interests

The enemy will probably attempt to reduce the effectiveness of our C4 system and degrade the ability of our AWACS aircraft to perform its mission.

Scenario 7: OPERATION THIN LINE

Background

During the past seven months an anti-Christian terrorist group has been active in the urban coastal cities in Eritrea, Djibouti and Somalia. The latest bombing claimed the lives of 178 Christian parishioners. Elusive and highly intelligent, the terrorist group has evaded all attempts at capture. A break in the case occurred when a trivial lead turned up some disturbing information. The group was apparently being sponsored by right wing, Islamic fundamentalists in Yemen. When the information was divulged to the world's media, Yemen quickly disavowed any knowledge of such a group. Activities associated with the terrorist group subsided for a while in the wake of the news.

Just before the terrorist group's next attack, information about the operation was leaked to authorities. The mission was foiled and the Djibouti authorities arrested 11 Yemenis army commandos. Yemen immediately demanded they be set free. Djibouti officials ignored the demands and proceeded to try them as criminals. As the prisoners were being transferred from the holding facility to the infirmary for medical checks, another Yemenis commando team rescued the captives, killing all the guards and police officers in the process. Yemen issued a statement defending their actions and vowed to continue such anti-Christian operations as long as necessary to rid the region of any influence of such "infidels." Eritrea, Djibouti and Somalia formed an alliance and demanded the Yemenis criminals be brought to justice, if not first by internal means, then possibly by external military pressure. Yemen's lack of response prompted the Christian alliance to declare war and enact their own brand of justice.

Force List

Enemy Nations: Yemen.
Friendly Nations: Djibouti,Eritrea,Somalia,USA.

Objectives

You must first attack and destroy enemy air force assets. After reducing the effectiveness of their air power, attack key political targets in a statement of power.

Possible Alternatives

Be prepared to attack targets that will reduce the enemy's ability to engage in an extended conflict.

Enemy Interests

At this point, nothing is known about the enemy's intentions.

Scenario 8: OPERATION SEA CONTROL

Background

Djibouti is holding their first three-party presidential election. The front runner is a staunch right-wing conservative named Igman Bushir. The next closest candidate still represents a conservative platform, but not as radical as Bushir's. Because of his Christian beliefs, the popular candidate is not well liked in the Arab world. Although not Anti-Arab, Bushir has made it clear that Yemen has too much control in the Red Sea and that power over commercial shipping should be shared with Djibouti.

After the presidential election votes are tallied, Bushir wins. At his inauguration, Bushir is shot. His wound proves fatal and control of the nation passes to the vice president. The gunman is arrested and turns out to be a radical Yemenis student, studying in Djibouti. The new president has the assassin publicly executed, and in his follow up address to the nation, declares a state of war with Yemen.

Force List

Enemy Nations: Yemen, Russia.
Friendly Nations: Djibouti, China, United Kingdom, USA.

Objectives

Your first attacks will be against political targets in Yemen as a response to the continued support Yemen has provided to anti-Arab sympathizers in the region.

Possible Alternatives

Other important centers of gravity in Yemen include their air force and C4 system. Be warned that, in this part of the world there is always the possibility of hidden force agreements between countries. Try not to offend neighboring nations and cultures or you run the risk that they might also become embroiled in the conflict.

Enemy Interests

The enemy will use their powerful air force to try to stop you. They may also try to attack your military hardware manufacturing facilities, which they have interpreted as one of your weaknesses.

Scenario 9: OPERATION SEA BREEZE

Background

A small coastal town in Somalia reported that several hundred residents became violently ill just after 10 O'clock in the morning. As medical help arrived, the condition of the affected townspeople worsened. By nightfall over half of the town's population had died, and what was left was in critical condition. Doctors speculated that the symptoms were that of a nerve agent, although no reagent was found at the site of the carnage. Two weeks later a similar incident occurred in southern Djibouti, again there was no evidence left of what had actually caused the sicknesses and the deaths.

Over the next week, there were several incidents of adrift fishing vessels being found, on which the crew was dead and or missing. Autopsy reports confirmed that the fishing crews had perished in the same manner as the residents of the two small towns. A young surgeon in Djibouti determined to find the cause of the catastrophes plotted the last known position of the boats on a map. He made a
startling observation. In both cases, the fishing crews had been well offshore the affected towns and in both cases the fishing crews had perished before the towns were even affected. He drew a line from the towns through the area of the fishing vessels until the line hit land. Both of the lines met in a coastal area of Yemen known for it's secret military research facilities. As a final check, the young doctor found the weather records for the wind speed and direction on the days of the attacks and it all matched up perfectly. Yemen had to have been conducting chemical or biological weapons testing and have also been using the surrounding nations as test subjects.

Yemen vehemently denied all accusations while they quickly dismantled the research facility. Intelligence reports seemed to indicate that the research was still being conducted, although no one except the Yemenis knew where.

Force List

Enemy Nations: Yemen.
Friendly Nations: USA, Djibouti, Somalia.

Objectives

Take out all industrial research sites in Yemen in an attempt to curtail their chemical and biological weapon research. Intelligence has indicated that these facilities may now be located within government buildings.

Possible Alternatives

None at this time.

Enemy Interests

The enemy will most likely continue to strike at you while you are trying to locate and stop the weapons research.

Scenario 10: OPERATION URGENT SHIELD

Background

Northern Ethiopia is home to several nomadic tribes which have maintained a “loose ownership” of their hunting and farming grounds on which they live. When oil reserves were discovered in the area, the government annexed the land, but let the tribes continue their way of life on the government owned property. As oil rigs and petroleum company workers arrived and setup living areas the land area used by the tribes began to shrink. This action caused a lot of pressure between the two groups. The tribes desired to have their land holdings back and the oil company, on the other side, wanted to rapidly exploit the oil rich ground. Minor skirmishes occurred as the two sides struggled for control of the land. The oil company took their problem back to the government. Motivated by oil money, the
government dispatched the army to get control of the situation. The government troops moved in and began to systematically “exterminate” the tribe members.

Word of the massacre spread quickly throughout the tribes and a mass exodus to Eritrea ensued. Overwhelmed by the number of Ethiopian refugees, Eritrea with UN support, setup several
humanitarian aid camps around major ports to help house the homeless tribes people until other accommodations could be procured. Ethiopia was angered that Eritrea and the UN had intervened in what was thought to be strictly an issue of “national concern.” In response to Ethiopia’s threats, Eritrea closed down all Ethiopian oil shipping. China, who was heavily reliant on Ethiopia’s oil,
condemned Eritrea’s shipping embargo against Ethiopia. The Chinese agreed that the refugee situation was a matter of internal unrest that Ethiopia should be left to resolve by itself. A UN delegation,
headed by the US and Russia sided with Eritrea. Angered by the loss of revenue over the suspension in shipping privileges, Ethiopia conducted surprise air strikes against Eritrea. Once again the region was embroiled in war.

Force List

Enemy Forces: Ethiopia, China.
Friendly Forces: Eritrea, USA, Russia.

Objectives

Your objective is to defend Eritrea by attempting to reduce the Ethiopia’s air power. In concert with your primary objective you must target C4 nodes in an attempt to “blind” the enemy.

Possible Alternatives

None at this time.

Enemy Interests

It is postulated that the Ethiopian decision makers will want to destroy friendly shipping capabilities in response Eritrea’s shipping embargo. Not much is currently known about what the Ethiopians and their allies are doing.

The F-22

Introduction

The Lockheed F-22 Raptor is a fighter uniquely optimized for the air superiority role. It represents a quantum leap in capability over its predecessor, the McDonnell Douglas F-15 Eagle. Key to this role is the ability to see and shoot before an enemy is aware of any threat, so reducing combat losses - what Lockheed-Martin refers to as ‘first-look, first kill’ capability. The F-22 uses stealth technology to remain undetected for longer, shares data between command aircraft and fighters and merges onboard and off-board sensor information into one coherent display. The pilot is able to alter his stealthiness by altering emissions from active sensors and jammers, simply by adjusting the EMCON (emission control) level.

In a secondary strike role, stealth and smart weapons combine to aid undetected penetration of enemy airspace, with accurate delivery of tactically efficient weapons.

The F-22 receives target information from active and passive sensor suites on-board and via data link from off-board sensors on other aircraft such as AWACS and friendly fighters. For the first time in a fighter aircraft, this information is fused together to build one overall picture of any given situation, instead of each detection system feeding its own dedicated display. Separate displays increase the pilots workload, while ‘sensor-fusion’ techniques reduce it dramatically.

Stealth technology has helped determine the shape of the F-22 (hence its angular fuselage and wings), so that the aircraft’s position is not easily given away to hostile radar. Equal consideration has been given to the detection systems and avionics so that they will do little to give away the plane’s position. A normal radar sends out a concentrated signal and detects return echoes

making it an inherently non-stealthy device. An opponent’s radar warning receiver may detect its signal. The F-22’s radar has been specially designed so that its energy is distributed over a broad spectrum, making it very hard to detect. It is known as a Low Probability of Intercept (LPI) radar and is controlled by the aircraft’s EMCON (Emissions Control) setting.

To a large extent the F-22’s systems think for themselves, sharing the workload in the event of threat or damage. The EMCON system automatically adjusts the F-22 sensors and defensive aids to deal with potential threats, although manual EMCON override is available should the need for different tactics arise.

Total Air War has been modeled on these features, using information available about the F-22 and the design concepts used in its construction.

Avionics

Onboard systems comprise radar, IRST (Infra Red Search and Track), RHAW (Radar Homing And Warning), IFF (Identification Friend or Foe), active jammers and the MAW (Missile Approach and Warning) systems. Of these, the radar and jammers are active devices that could give away the aircraft's position from the energy being sent out. The others are passive, or listening, systems. All aircraft systems that emit energy and could therefore alert the enemy, such as active sensors or radios, are controlled by the EMCON system.

EMCON Settings

The EMCON system is there to decide how to balance stealth against detection and jamming capability. There are five EMCON levels, controlled either automatically by the aircraft computers, or manually by the pilot. EMCON 1 is the stealthiest and EMCON 5 is the least stealthy, allowing the most use of radar and radio.

In its auto mode the F-22 would normally travel in the stealthiest mode, EMCON 1. After a potential enemy is spotted, the aircraft systems will gradually increase the EMCON condition as the opponent gets closer, in order to provide more data for targeting, or in the worst case, jamming. It increases EMCON in non regular steps based on the evaluated range of the enemies' detection systems and weapons.

By exploiting stealth, the pilot is able to stalk his target like a cat stalking a mouse, without the target ever being aware of danger. With each increase in EMCON, the pilot has more information with which to decide on a course of action (engage or not) and with which to target his weapons. At EMCON 3 he will be within AMRAAM firing parameters and have enough information for BVR (Beyond Visual Range) missile targeting. By the time the systems have reached EMCON 5, detection by the enemy is irrelevant because the aircraft will be most likely be in visual range. It should be noted that Russian fighters like the Sukhoi Su-37 employ the two pronged approach of using a very powerful radar to burn through any stealth advantage, then turning its radar off and handing over to passive IRST. The pilot is able to manually override the avionics and choose the EMCON condition best suited for chosen tactics, For example, on a strike mission where surprise is everything, the pilot may wish to remain stealthy, despite the proximity of enemy fighters.

When using radar guided Air-to-Air missiles (such as the AIM120 AMRAAM) you must have an EMCON level at least 3 to launch. These weapons can not be launched at EMCON levels 1 and 2.

The avionics allow the classification and display of enemy aircraft and SAM control radar. By knowing what you are up against and by displaying the enemy's detection and weapons ranges, it is possible to sneak around the danger and keep the F-22 stealthy. In other words the F-22 pilot enjoys the rare ability to see his enemy yet not be seen and therefore knows just how far his enemy is able to see and strike.

EMCON level is selected in one of two ways. Firstly, by an MFD button in the cockpit for both manual and automatic EMCON level. Secondly by pressing E on the keyboard and choosing a level option; e.g. 1 for manual EMCON 1 etc., or option 6 for auto EMCON.

NOTE: EMCON is normally set to automatic.

The F-22 – Avionics

EMCON Steps

The EMCON steps have been based on the real F-22, but due to military sensitivity and game play reasons the device's abilities have been defined as follows:

EMCON 1

- The radar is off.
- The AMRAAM is disabled.
- The IRST is the primary on board detection system with a range of 50 miles. It can be used to target target and launch the Sidewinder air-to-air missile and the Maverick Air-to-Ground missile.
- The Radar Homing And Warning is on to a range of 50 miles. (RHAW warns of enemy radar activity, tracks and then classifies the source type).
- The Missile Approach and Warning is on. (The MAW system warns of enemy missile launches).
- The Communications radio is prevented from transmitting.
- The secure data link is set to receive.

EMCON 2

- The radar is on and is able to ID and track air-to-air contacts only.
- The AMRAAM is disabled, but the missile steering circle information is now displayed on the Air-to-Air HUD.
- The IRST is on with a range of 50 miles. It can be used to target and launch the Sidewinder air-to-air missile and the Maverick Air-to-Ground missile.
- The RHAW is active to a range of 100 miles. (The RHAW warns of enemy radar activity, tracks and classifies the source).
- The MAW is off. (The MAW warns of enemy missile launches).
- The Communications radio is fully on.
- The IFDL secure data link is set to both send and receive.

EMCON 3

- The radar is on and is able to ID, track and target air-to-air contacts.
- The AMRAAM is now enabled.
- The IRST is on with a range of 50 miles. It can be used to target and launch the Sidewinder air-to-air missile and the Maverick Air-to-Ground missile.
- The RHAW is on to a range of 150 miles. (The RHAW warns of enemy radar activity, tracks and classifies the source).
- The MAW is off. (The MAW warns of enemy missile launches).
- The Communications radio is fully active.
- The IFDL secure data link is set to both send and receive.

EMCON 4

- The radar is on and is able to ID, track and target air-to-air contacts.
- The AMRAAM is enabled.
- The radar is also able to ID track and target large ground mobile and ship targets.
- The IRST is on with a range of 50 miles. It can be used to target and launch the Sidewinder air-to-air missile and the Maverick Air-to-Ground missile.
- The RHAW is active to a range of 200 miles. (The RHAW warns of enemy radar activity, tracks and classifies the source).
- The MAW is on. (The MAW warns of enemy missile launches).
- The ability to manually launch drones and chaff is enabled.
- The Communications radio is fully active.
- The IFDL secure data link is set to both send and receive.

EMCON 5

- The radar is on and is able to ID, track and target air-to-air contacts.
- The AMRAAM is enabled.
- The radar is able to ID track and target all ground mobile and ship targets. Air-to-

Ground missiles requiring radar for targeting (Harpoon) are enabled for launch.

• The IRST is active, with a range of 50 miles. It can be used to target and launch the Sidewinder air to air missile and the Maverick Air-to-Ground missile.

• The RHAW is active to a range of 250 miles. (The RHAW warns of enemy radar activity, tracks and classifies the source.

• The MAW is fully active. (The MAW warns of enemy missile launches). The defensive suite of drones, ECM, chaff and flares is fully enabled.

• The Communications radio is fully active.

• The IFDL secure data link is set to both send and receive.

Shoot lists

Detected targets are put into a 'Shoot List' in the sorted order of engagement, either automatically via a key press or manually via the MFDs. Priority of threat is assessed from enemy bearing, type and speed. A shoot list for the currently selected weapon type is built by pressing T on the keyboard.

Note: the shoot list is normally built automatically. Targets can be put into the shoot list manually by padlocking the target using F2 or F3 on the keyboard and then pressing S. This is particularly relevant for targeting the AIM-9X Sidewinder and AGM-65 Maverick.

Targets can also be added manually by looking at the Situation or Attack MFDs and placing the cursor over a target and clicking. Each new click over a marked target will add it to the shoot list . Your weapons, when fired will engage the targets in the same order that you picked them.

The number of shoot list entries is directly related to the number of weapons carried, a separate shoot list being built for each weapon on board. The shoot list generation system prioritizes targets in center of HUD higher than the other potential threats. To prioritize something higher, place it in the center of the HUD, and press 'T'.

NOTE: an automatic shoot list can be added to manually until all weapons carried have a target and hence a position in the list. Information about targets is displayed in the bottom left corner of each MFD if you place the cursor over a target on that MFD.

The shoot list can be cleared with the 'U' key. This is useful in situations where you build an automatic shoot list and then need to clear to build a manual shoot list.

Cycling targets

There are 2 methods for cycling targets: automatic and manual. The Shoot lists are normally set to cycle a **target manually**, i.e. you will have to cycle your aim to the next target after firing at it by pressing the C key to cycle through the list forwards, or the X key to cycle through the list backwards.

Automatic cycling is available as on the real F-22, by going to the Attack MFD and pressing the 'Auto Cycle Targets' button. Each time you fire a selected weapon, the target for your next weapon will be shifted to the next target in the SHOOT list. This means that you can quickly engage a number of targets in rapid succession, just by firing each time the SHOOT cue appears. Auto target cycling can be toggled on / off using 'Shift C'. When you only have one pass at the enemy, you might want to set the selected weapon to launch as a **salvo fire**, or **ripple fire.** In salvo fire, all selected weapons will launch. In ripple fire, each weapon will launch when it has all the information it needs and is in range.

The F-22 – Avionics

This is done by pressing the relevant button on the Systems MFD. The number of weapons to be launched as a salvo or ripple is set in the Systems MFD, before you engage. One press of the trigger will start the sequence.

Sharing targets with your wingman

Information on targets is shared through the IFDL (Intra Flight Data Link), enabling you to target and prioritize the weapons of your wingman by either pressing F2 or F3 on the keyboard. Then you simply ask your wingman to engage by pressing TAB to talk to Wingmen, option 3 Combat, next option 1 *"ENGAGE MY TARGET"*. A quicker method is to press F2 (or F3) on the keyboard and then press M .

Infra Red Search and Track (IRST)

The IRST is a highly sensitive infrared camera that has the ability to magnify a target for display on the Up front MFD. This allows the pilot to visually identify targets at well beyond visual (eyeball) range. The IRST scans around a frontal arc and several degrees up and down. It operates in tandem with the radar in EMCON 2 and higher, being cued (pointed to) the currently selected target in the SHOOT list. The IRST will be slaved to the pilot's view if a padlock view is used (F2).

In EMCON 1 the IRST becomes the primary on-board search and track device, cued to a potential target by its heat emissions. As such it is a very stealthy means of acquiring targets. Target information gained by the IRST is pooled with all other sensor information allowing all air-to-air and Air-to-Ground guided weapons to be cued to their targets.

For additional information please refer to 'Shoot Lists' and 'Cycling Targets' above, together with entries on AMRAAM, Sidewinder and Maverick missiles.

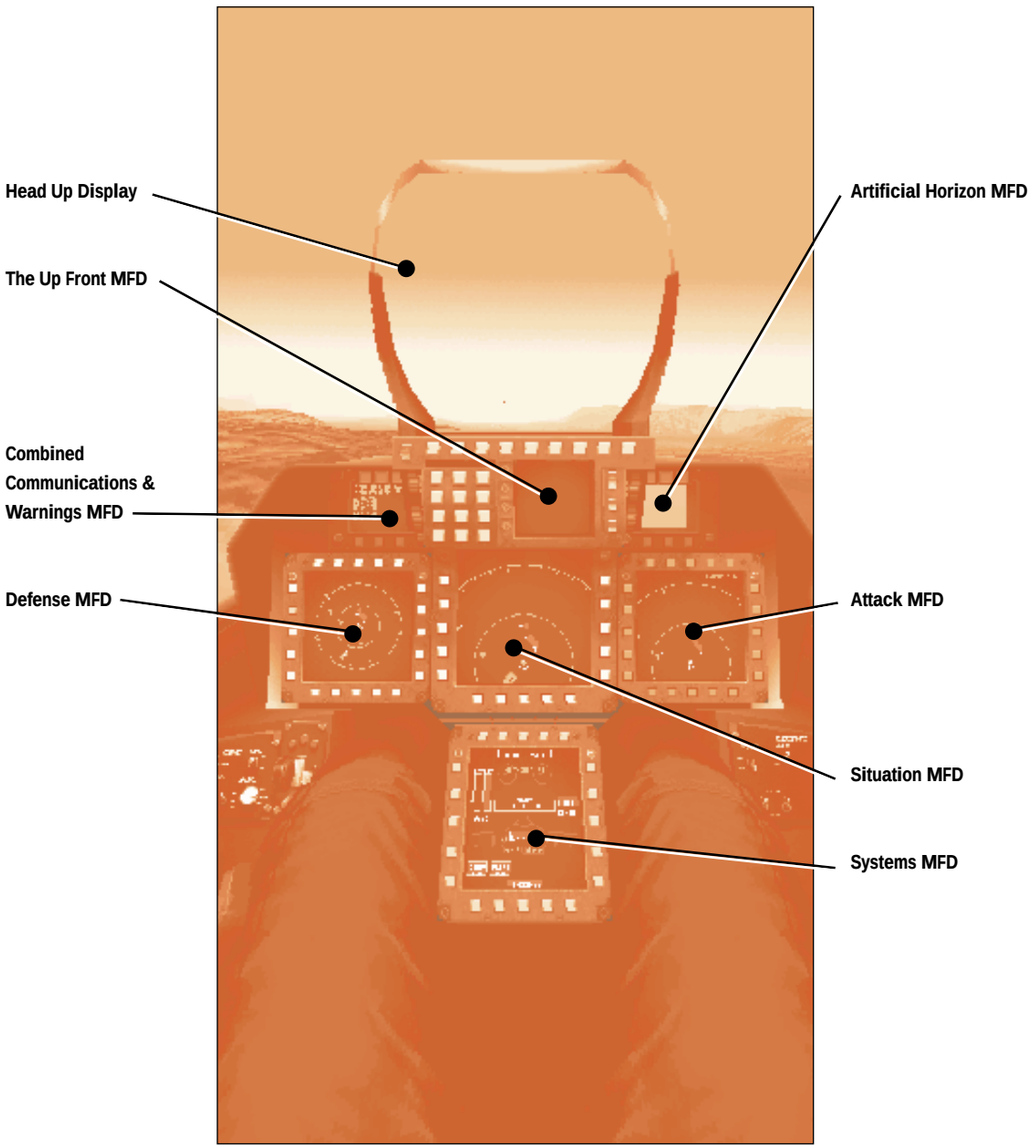
Removing HUD Clutter with the 'J' key

The 'J' key can now be used for removing clutter from the HUD to allow you to concentrate on the target at the head of your shoot list. The 'de-clutter' is a toggle on/off function and when toggled on turns off the following symbology in the air-to-ground and air-to-air HUD modes:

• Velocity vector
• The HUD Terrain following box
• Targets that are not currently at the head of the shoot list
• The radio frequency indicator
• The EMCON indicator

The F-22 – Avionics

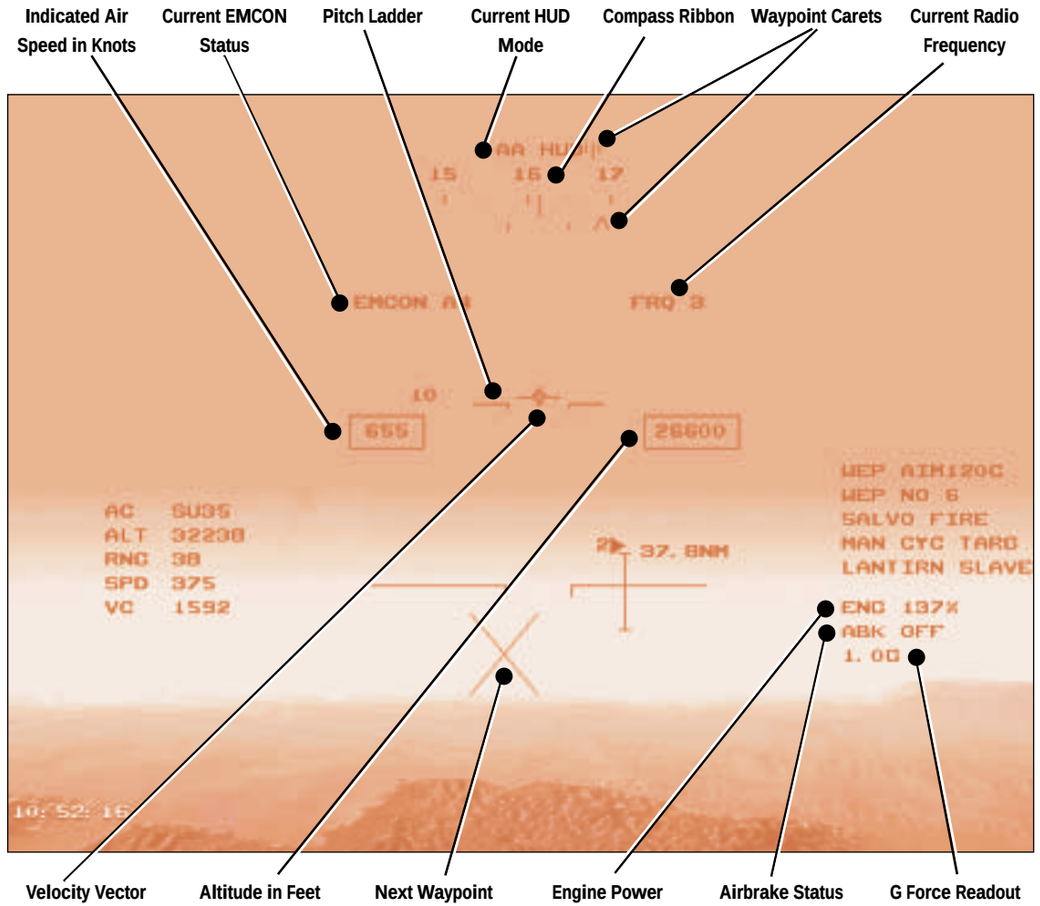
Cockpit Layout



The F-22 has a full 'glass' cockpit

The Head Up Display

The HUD is positioned in the pilot's line of sight and inside the front of his canopy. It is possible to cycle the HUD colors between bright red, dark green, bright green, or dark red and can be cycled through those colors by pressing the keyboard SHIFT H keys. Information useful to the pilot is shown on the HUD in 5 selectable modes, all of which can be selected by cycling through H on the keyboard.



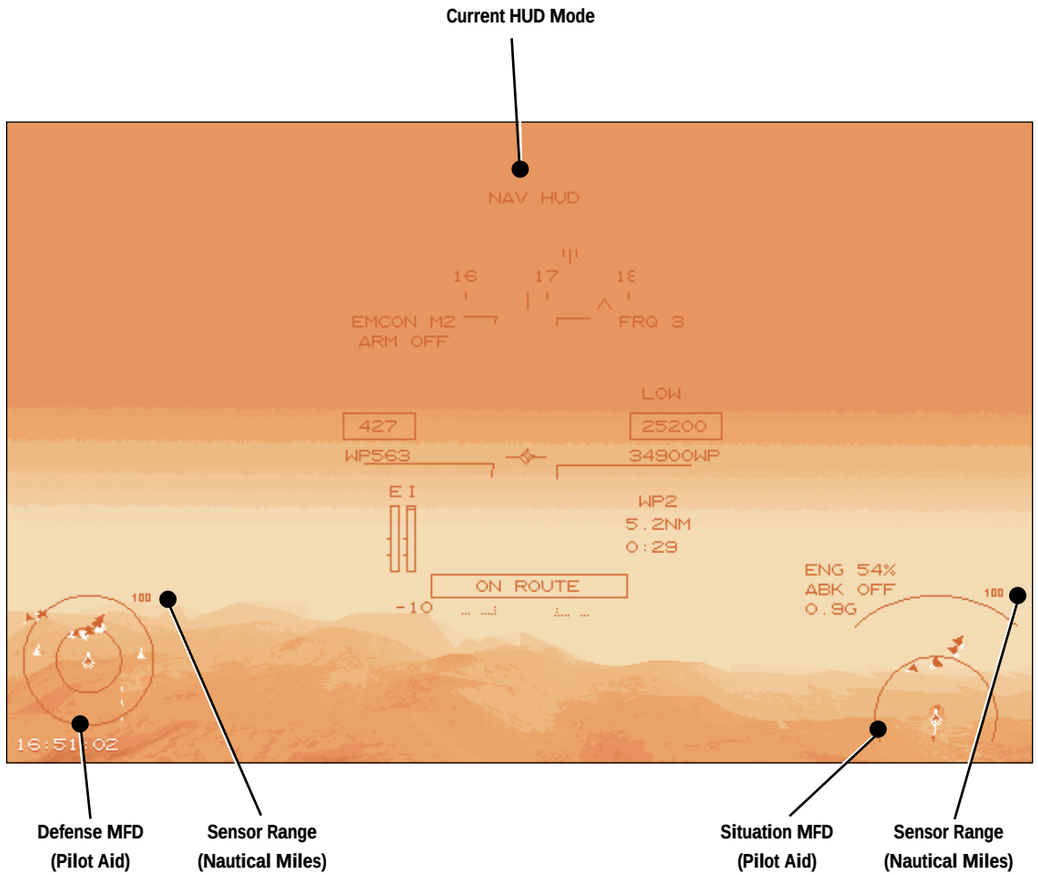
Common information in all F-22 HUD modes

The Helmet Mounted Display

Pilot Aids

Pilot aids overlays the Situation and Defense displays in the bottom corners of the screen. The pilot aids default to on in the 'Full HUD' view and their settings can be adjusted by pushing 'Shift G'. The three settings are:

- Full HUD pilot aids (Default)
- Full HUD and virtual cockpit pilot aids
- Pilot aids off

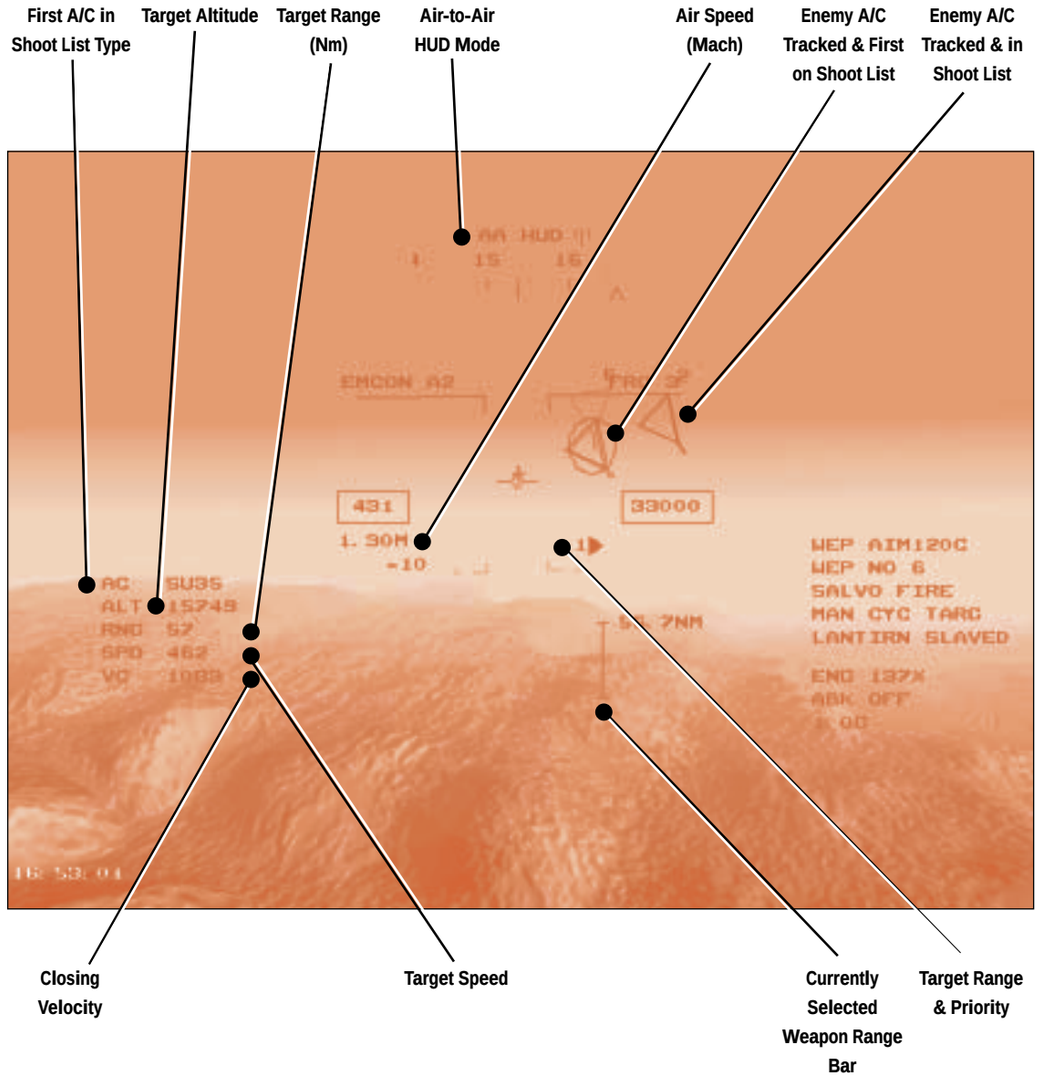


Helmet mounted information

For additional information please refer to the Online help (main menu, help button).

Air-to-Air Weapons HUD

The Air-to-Air weapons HUD is selected by pressing RETURN on the keyboard, or by pressing H to cycle through the HUD modes. The Air-to-Air HUD shows all useful information for air combat.

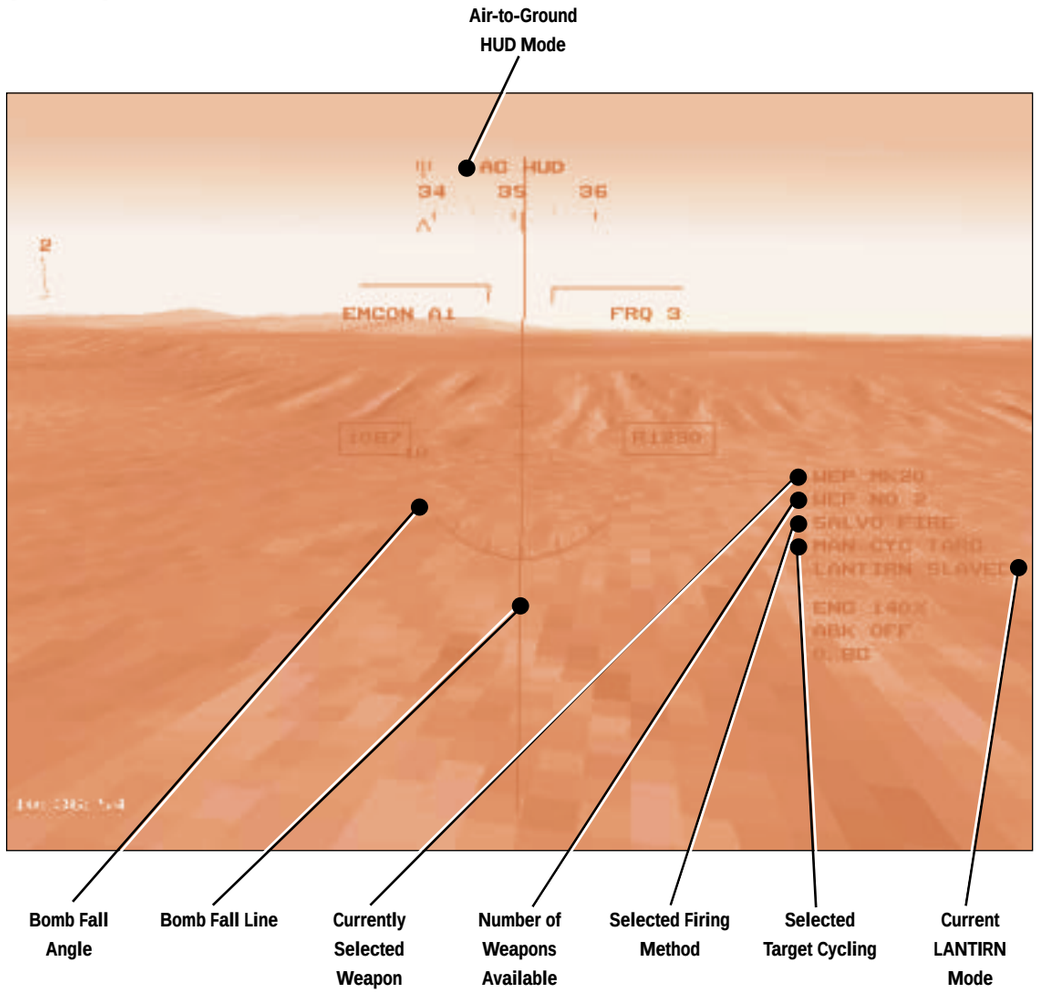


The AA HUD - essential information for Air-to-Air combat

The F-22 – Avionics

Air-to-Ground weapons HUD

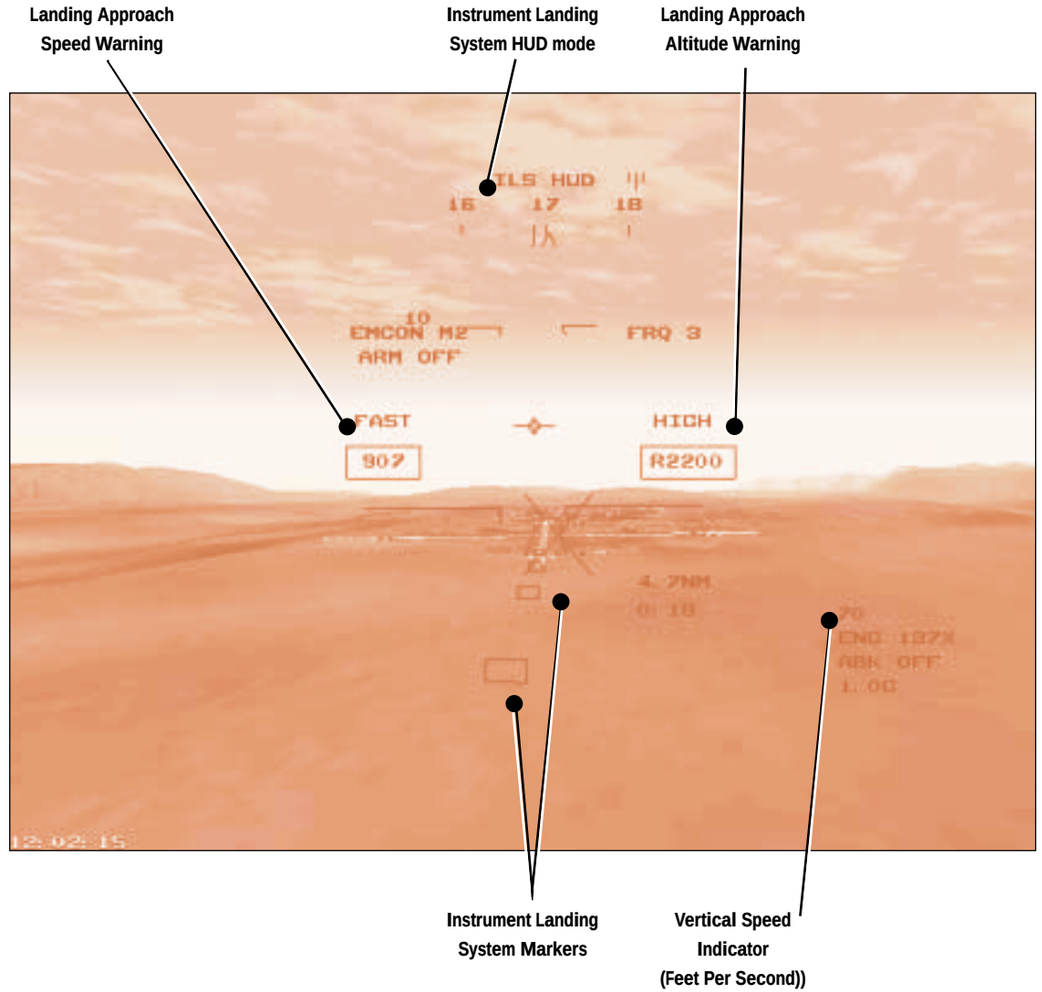
The Air-to-Ground weapons HUD is selected by pressing BACKSPACE on the keyboard, or by pressing H to cycle through the HUD modes. The Air-to-Ground HUD shows all of the useful information for targeting mobile or static ground targets.



The AG HUD - essential information for Air-to-Ground combat

Instrument Landing System HUD

The Instrument Landing HUD is selected by pressing H to cycle through the HUD modes and displays information to aid landing.



The ILS HUD - landing made easier

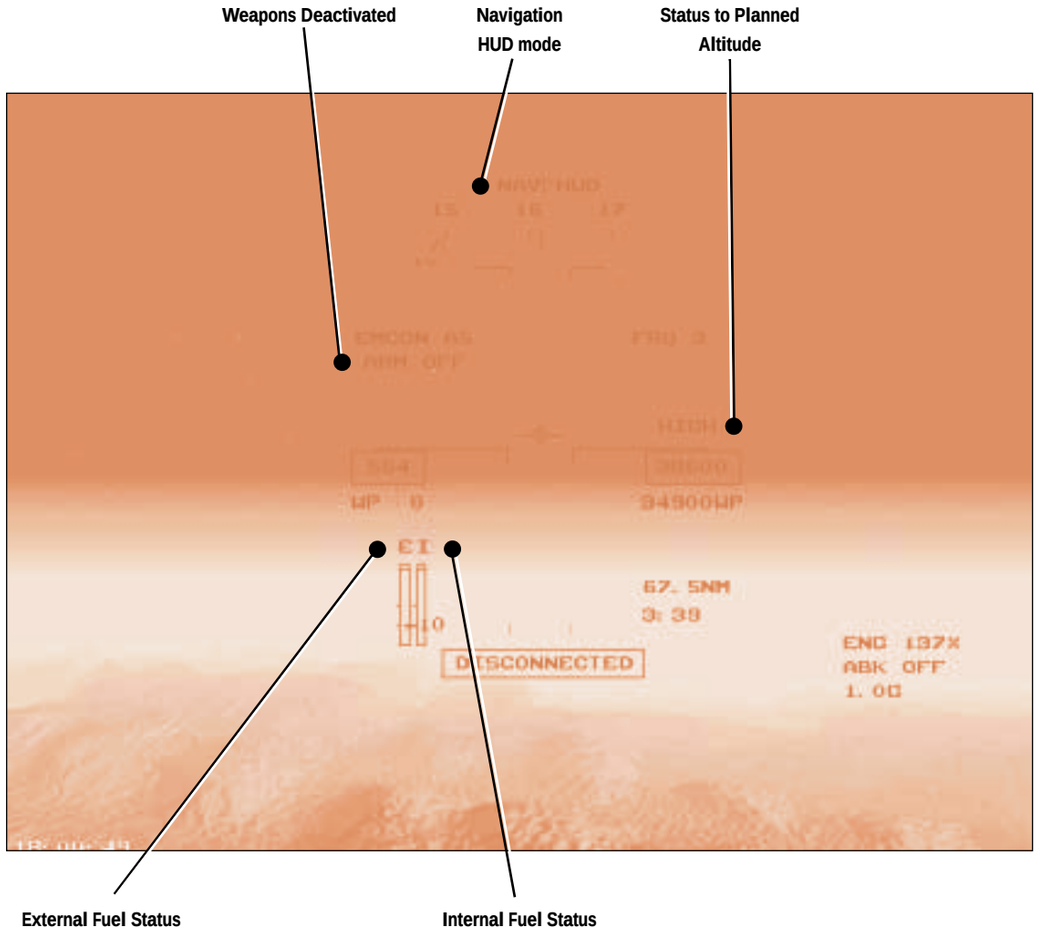
The HUD Terrain Following Box

To allow your F-22 to fly at low level your HUD shows a rectangle at the bottom of the display. As your plane flies lower the rectangle rises up the display. If you keep the velocity vector in or above the box then your plane is in no risk of hitting the ground.

The F-22 – Avionics

Navigation HUD

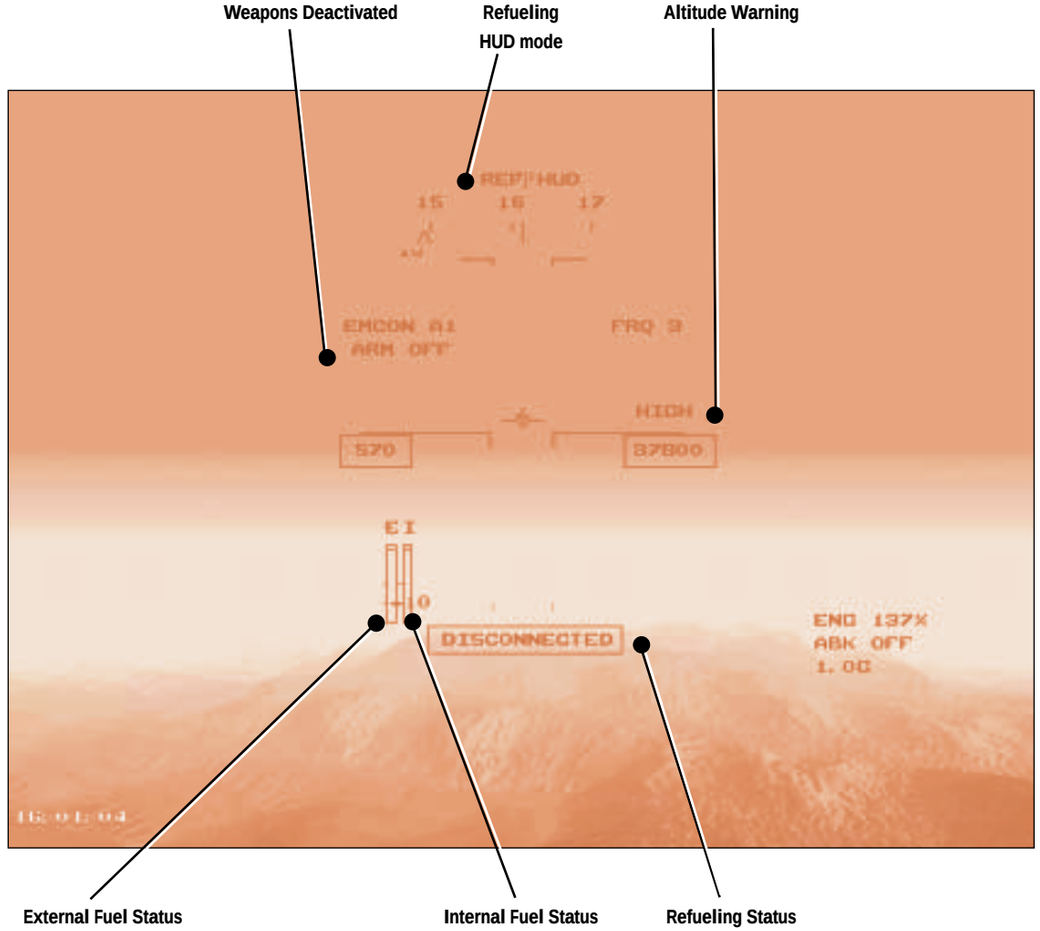
The air navigation HUD is selected by pressing H to cycle through the HUD modes and displays useful information for navigation around the world.



The Navigation HUD - find your way from A to Z

Air Refueling HUD

The air refueling HUD is selected by pressing H to cycle through the HUD modes and displays all useful information for in-flight refueling.



The Refueling HUD - essential for this difficult maneuver

The F-22 – Avionics

Indicated Targets

Targets are marked on the HUD and MFDs as shown in the accompanying diagrams:

	HUD Symbology	MFD Symbology	MFD Color
Enemy Aircraft (Subsonic)			Red
Enemy Aircraft (Supersonic)			Red
Enemy Aircraft Radar Coverage			Red
Friendly Aircraft			Green
Unknown Aircraft			Yellow
Enemy Ship			Red
Friendly Ship			Green
Unknown Ship			Yellow
Enemy Ground Mobile			Red
Friendly Ground Mobile			Green
Unknown Ground Mobile			Yellow
Enemy Missile			Red
Friendly Missile			Green
Enemy Static Target			Red
Enemy SAM or Radar Site (Circle shows Radar Coverage)			Red
Wingmen			Light Blue
Strike/High Value Asset (in your mission)			White
Wild Weasel (in your mission)			Dark Yellow
Escort (in your mission)			Light Yellow

HUD Targeting Sequence

1. The Target is being Tracked **2. The Target is Locked and in the Shoot List** **3. The Next Target in the Shoot List** **4. Weapon Launched at Individual Target**

MFD Targeting Sequence

1. The Target is being Tracked **2. The Target is Locked and in the Shoot List** **3. The Next Target in the Shoot List** **4. Weapon Launched at Individual Target**

The Multi Function Displays

In the F-22 cockpit their are seven MFDs. See the cockpit diagram in the Avionics description above. *For additional information please refer to the Online help (main menu, help button).*

The Combined Communications and Warnings MFD

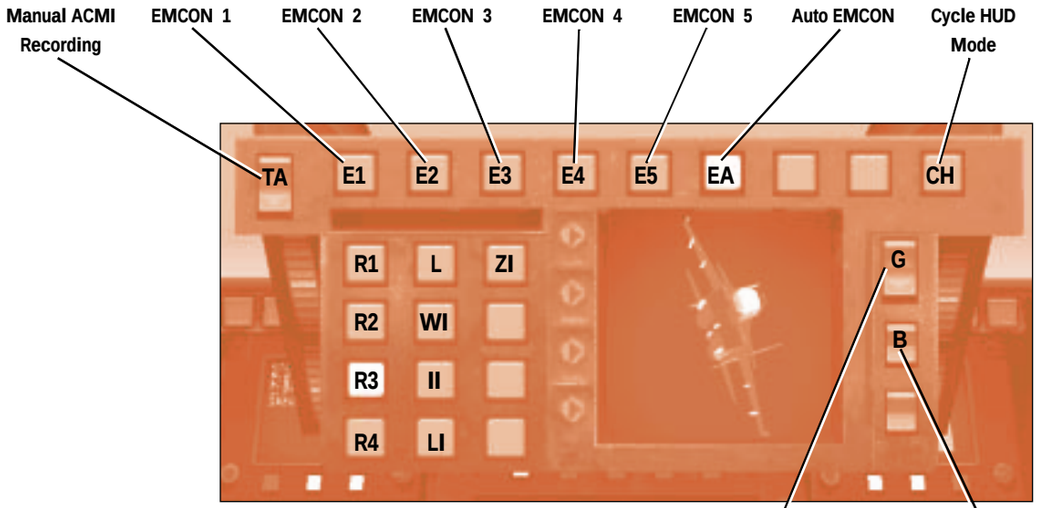
This MFD has one mode: Display text transcriptions of messages sent to you audibly, plus the currently selected communications radio frequency. Interspersed with the messages will be system malfunctions and warnings text.

Text corresponding to audio and warning messages are displayed on this MFD

The F-22 – Avionics

The Up Front MFD

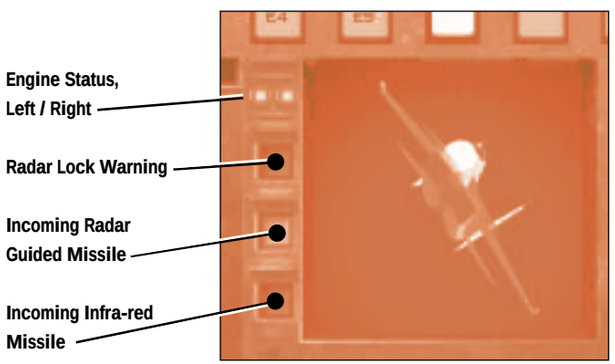
This MFD has two modes:
1. Display aircraft target images detected by the IRST when the HUD is in Air-to-Air mode.
2. Display ground target images detected by the IRST when the HUD is in Air-to-Ground mode.



R1 - Radio Frequency 1
R2 - Radio Frequency 2
R3 - Radio Frequency 3
R4 - Radio Frequency 4

LI - LANTIRN Image
WI - Weapon Image
II - IRST Image
LI - Lock Image to Selected Weapon

ZI - Zoom Image



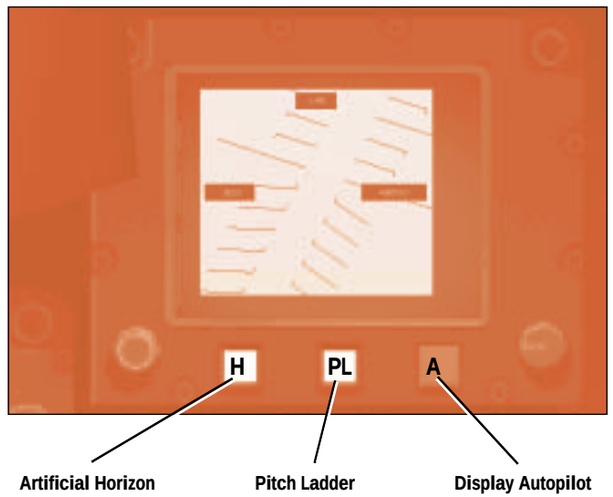
IRST display and Warning lights

Avionics Audio Cues

The F-22 avionics have a female voice that issues warnings, known affectionately to pilots as “Bitchin’ Betty”. Betty is intended to provide an audible cue or warning of importance to the pilot when his mind is on something else! However, Betty can be turned on/off by pressing the relevant button on the Systems MFD. Further cues and warnings are given by assorted synthesized sounds.

The Artificial Horizon MFD

This MFD displays the Artificial Horizon.

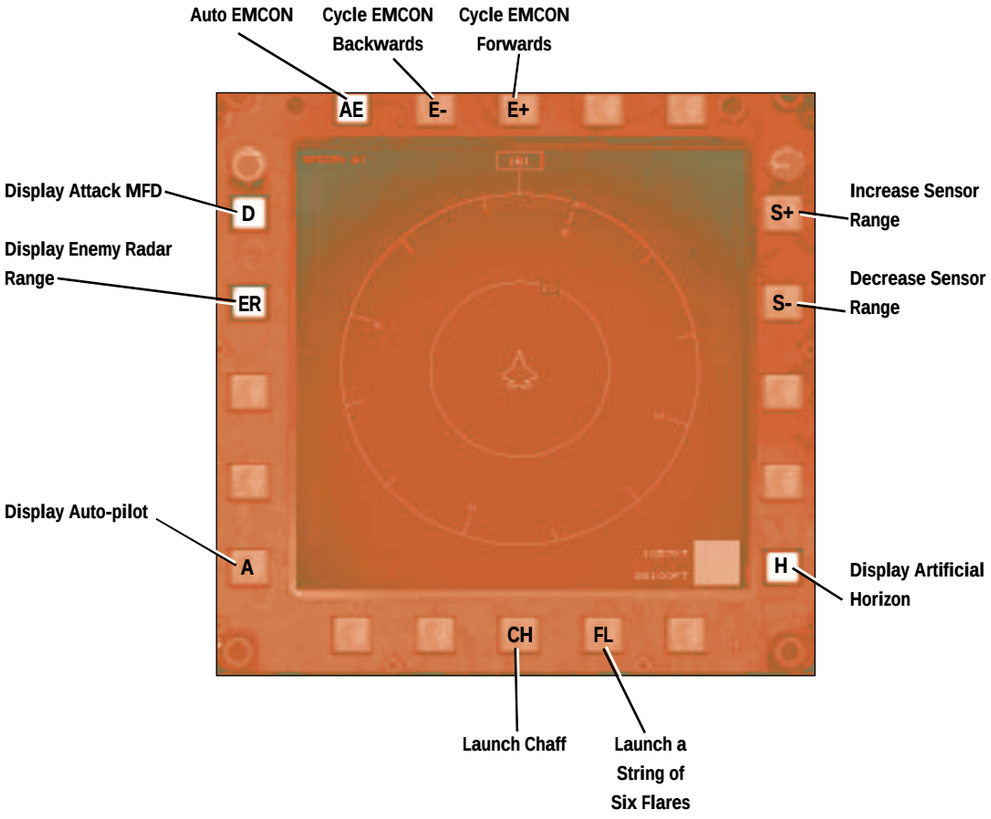


Artificial horizon - useful for instrument approaches

You can display the artificial horizon in other MFDs such as the System MFD or LANTIRN MFD.

The Defense MFD

This MFD has two display modes:
1. Display sensor information with the addition of enemy radar and weapons ranges.
2. Display the interactive Auto-pilot

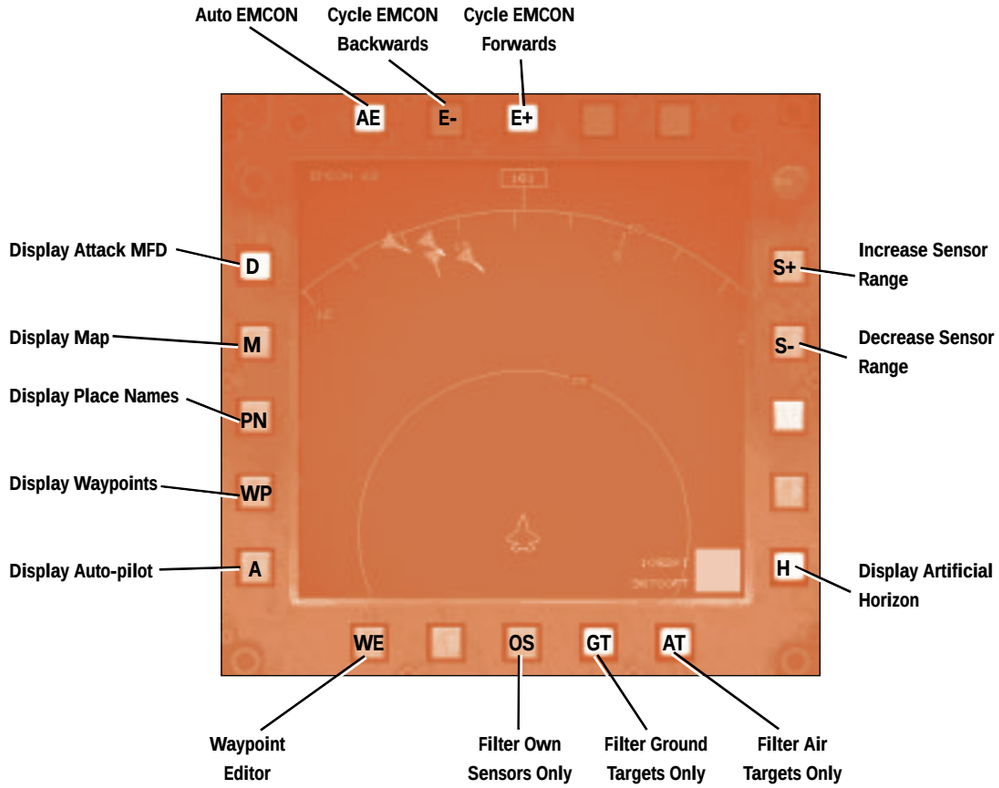


Defense - critical information about your enemies offensive stance

The F-22 – Avionics

The Situation MFD

This MFD has two display modes:
1. Display sensor information of the overall situation.
2. Display the interactive Auto-pilot



Situational awareness - the moving map underlies all detected targets

Kill Boxes in Training Missions

Kill Boxes are shown as red boxes on the 'Situation' and 'Attack' MFDs. Any ground based unit (tanks and SAMs etc.) contained by the box are to be regarded as the enemy.

Mission Targets

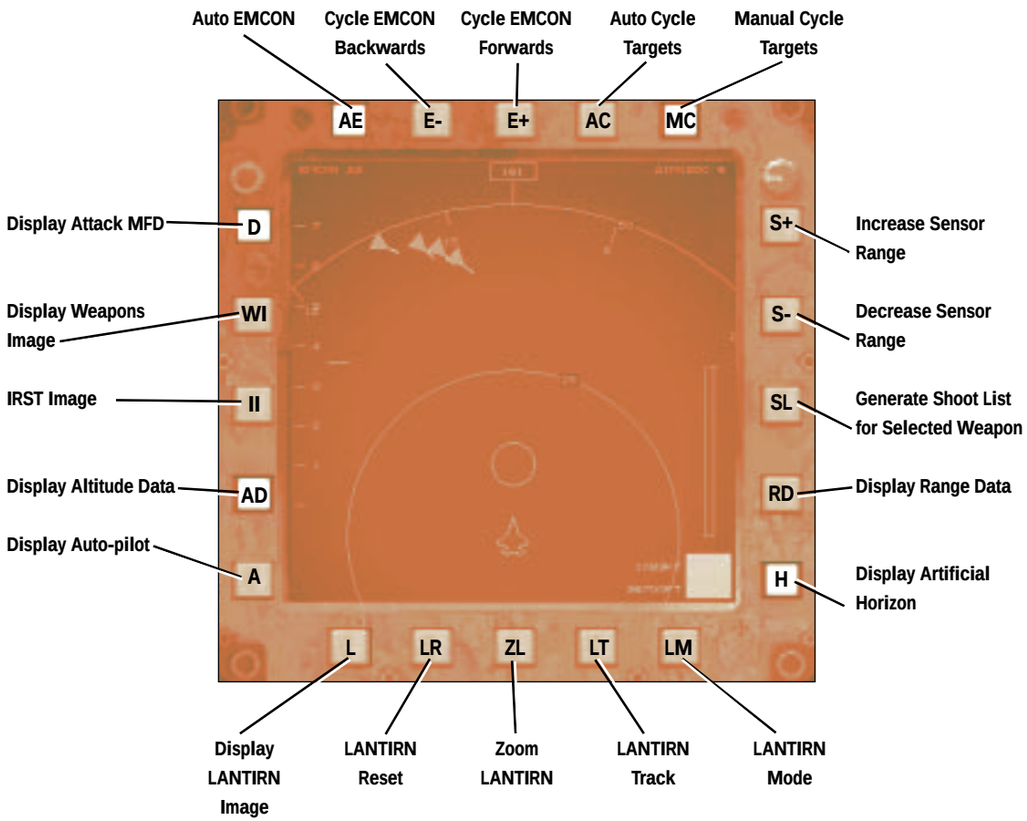
Mission targets are indicated in the Defense, Situation & Attack MFDs by the letter 'T'. (This is only available at Easy & Medium difficulty settings).

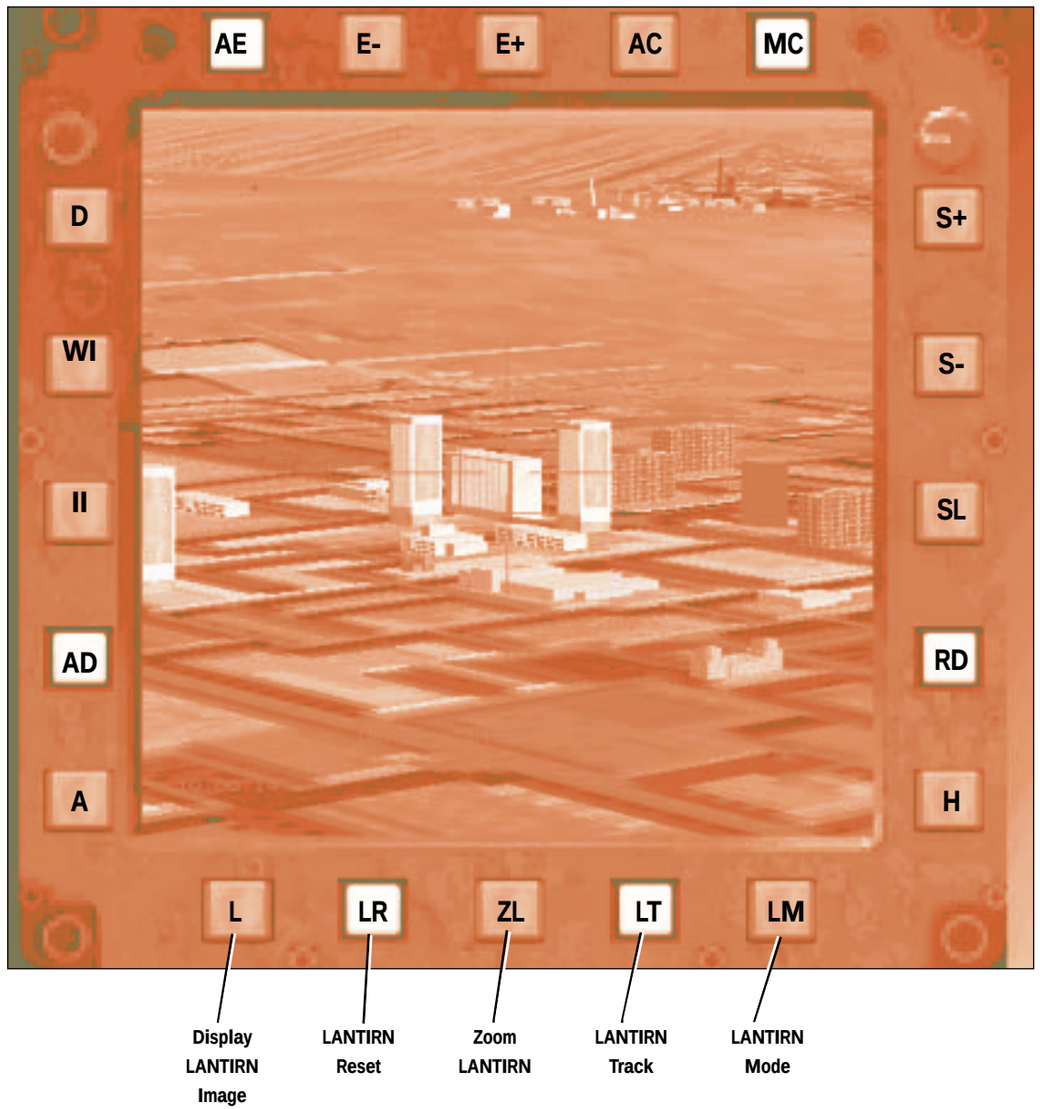
The F-22 – Avionics

The Attack MFD

This MFD has four modes:

1. Display sensor information with the emphasis on ranges and heights.
2. Display the LANTIRN TV image from the under fuselage 'eyes' for targeting laser guided weapons.
3. Display the interactive Auto-pilot
4. Display an image sent back by a camera equipped weapon, (such as a Maverick air-to-ground missile).





Attack - everything you need to know to engage the target

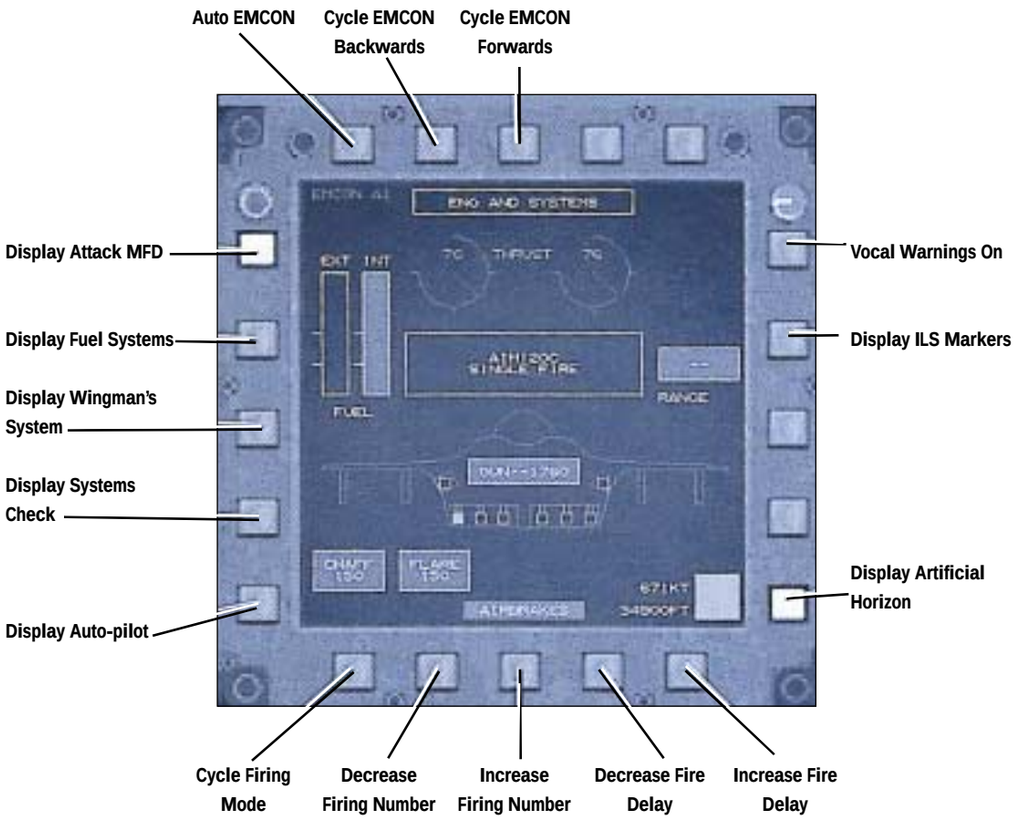
LANTIRN - for precision ground attacks with guided weapons

The Systems MFD

This MFD has five modes:

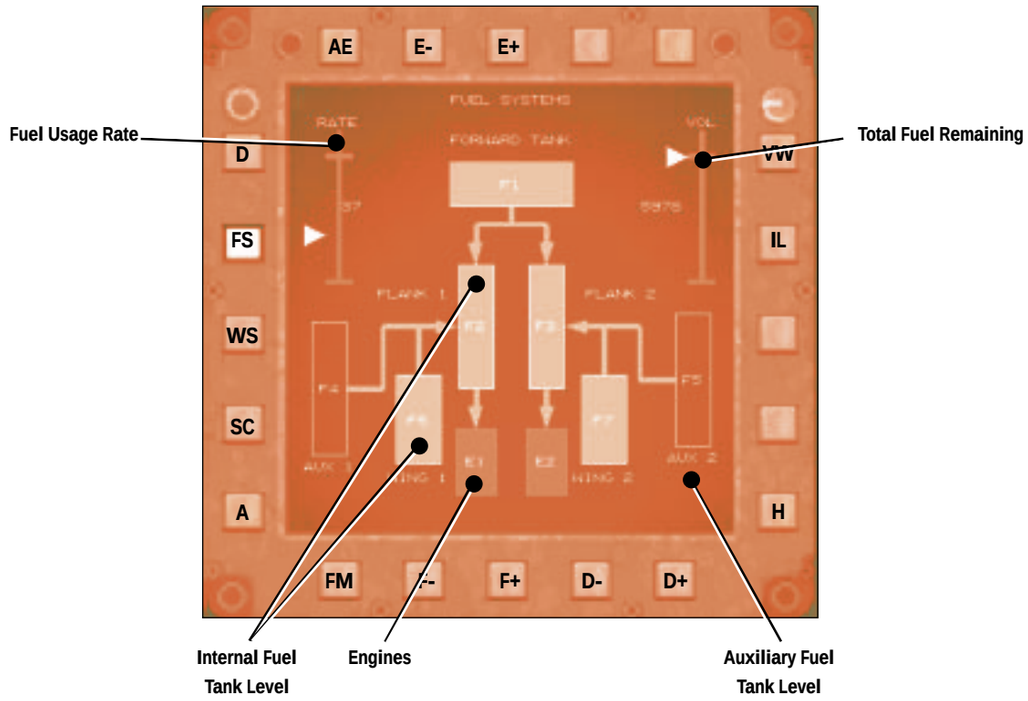
1. Display the general systems of immediate importance to the pilot.
2. Display the fuel systems.
3. Display wingman information
4. Display systems status.
5. Display the interactive Auto-pilot

NOTE: on the systems MFD are buttons which will alter the firing of weapons, the options are: single, ripple and salvo fire.



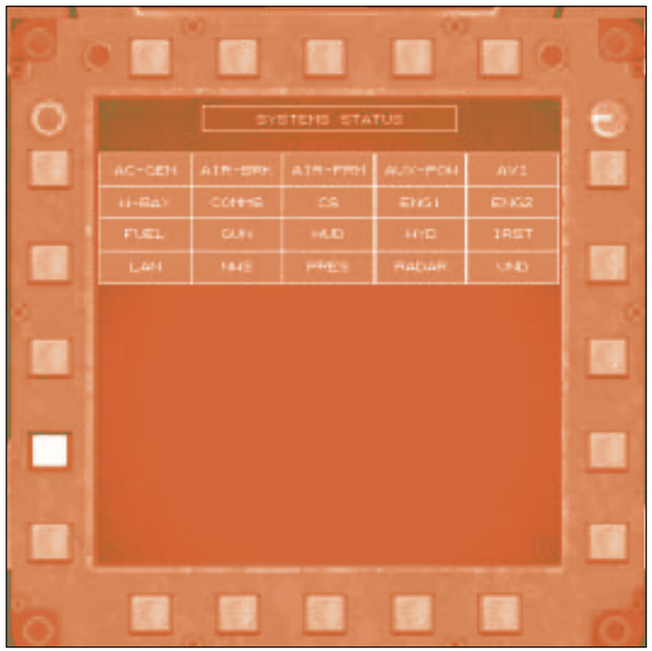
General systems (Wingman Mode) - engine fuel and weapons status at a glance

The Systems MFD



Fuel systems - fuel usage at a glance

The Systems MFD



A breakdown of the abbreviations used in the Systems Status MFD

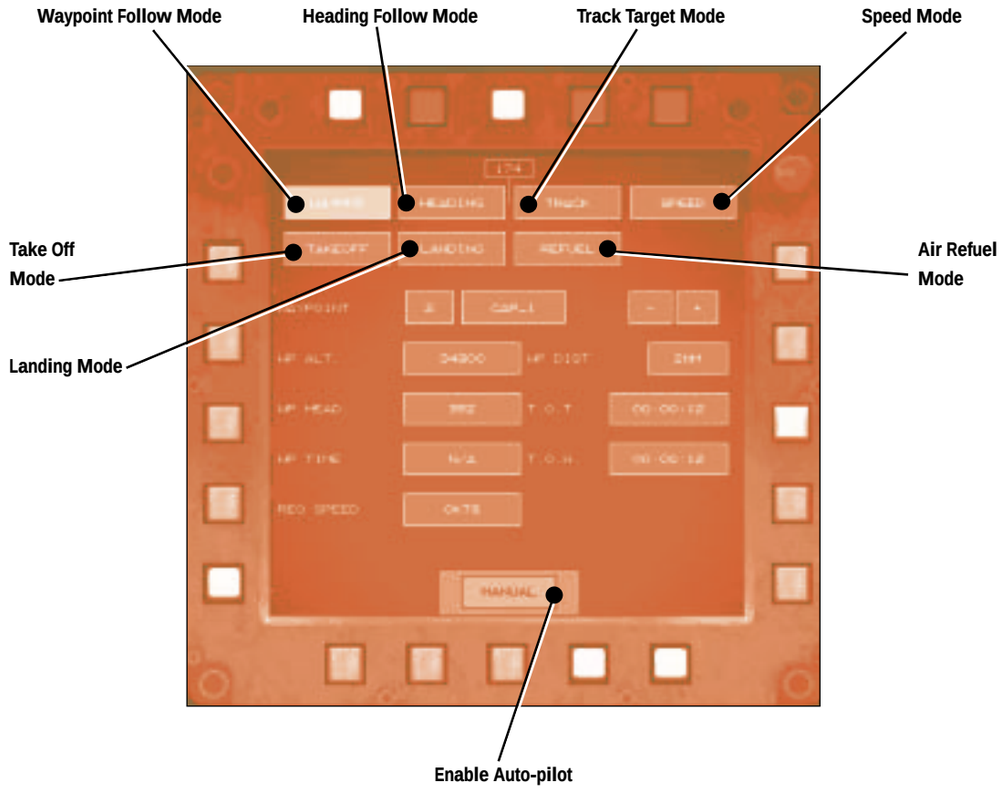
Generator	**Air Brake**	**Air Frame**	**Auxiliary Power**	**Avionics**
Weapons Bay	**Communications**	**Control Surfaces**	**Engine 1**	**Engine 2**
Fuel (Leak)	**Cannon**	**Head Up Displays**	**Hydraulics**	**Infra Red Search & Track**
LANTIRN	**Nose Wheel Steering**	**Cockpit Pressure**	**Radar**	**Under Carriage**

Green	Means that the system is fully functional.
Yellow	The system is damaged but still operable.
Red	That the system is badly damaged.
Flashing Yellow	The system is on fire.

Aircraft systems status - Check your Aircraft systems at a glance

The F-22 – Avionics

The Systems MFD



Auto-pilot - alter the Auto-pilot instructions

The F-22 – Avionics

The Auto-pilot

The Auto-pilot is capable of controlling the F-22 throughout all the phases of a mission. It will taxi the aircraft to the runway and automatically takeoff, follow a waypoint route and a predetermined heading, track targets, maintain a constant speed, aid air-to-air refueling and assist in landing and taxiing back to a parking apron. Engage or disengage at any time in flight, or on the ground.

When used for **take off**, you must have been given permission to taxi and replied by pressing Y on the keyboard. The auto-pilot must be in take-off mode.

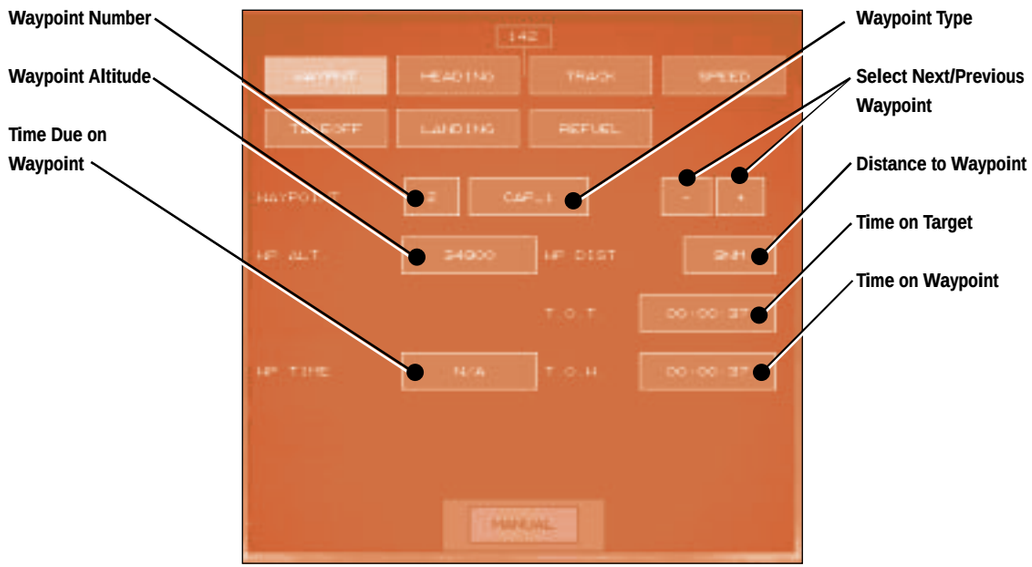
For **landing** you must have sought and been granted permission to land and replied by pressing Y on the keyboard. The auto-pilot must be in landing mode.

To **refuel** with the auto-pilot you must have sought permission to refuel and replied Y on the keyboard to the *'AFFIRM WEAPONS AND NOSE COLD'* message.

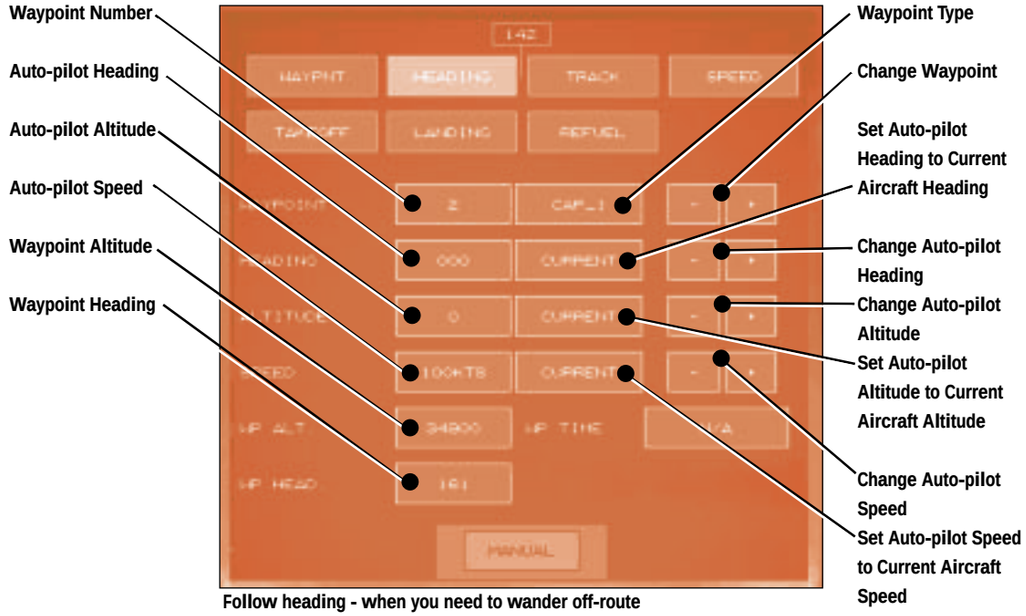
Select refuel on the auto-pilot, noting that the HUD should now be in refuel mode and form behind and to the left of the tanker. When the refueler gives you *CLEARED PRE-CONTACT* permission, engage the auto-pilot by pressing A on the keyboard.

The Auto-pilot is available on any one of the main MFDs and has the following modes:

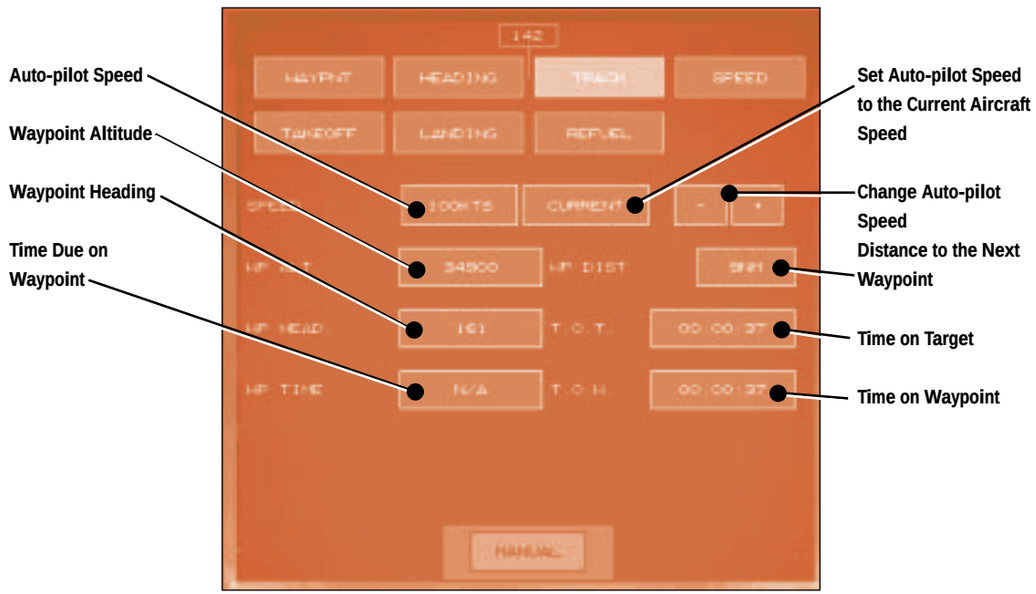
- Follow waypoint route
- Follow heading
- Follow first target in shoot list
- Follow a set speed
- Take off mode
- Landing mode
- Refueling mode



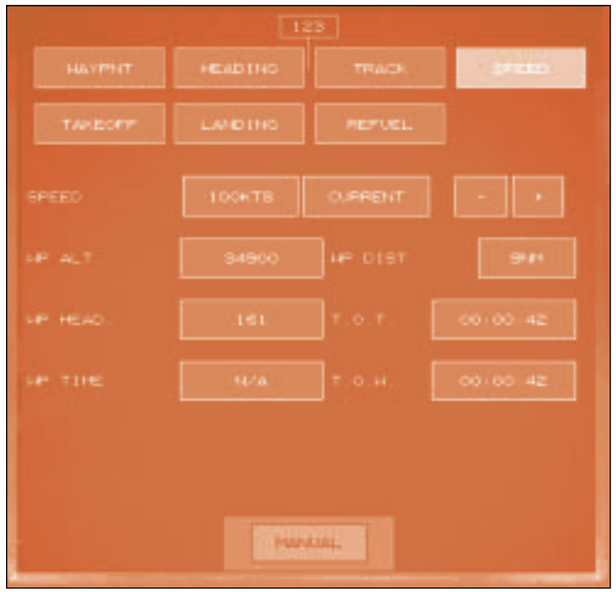
Follow waypoint - one of the auto-pilots many useful functions



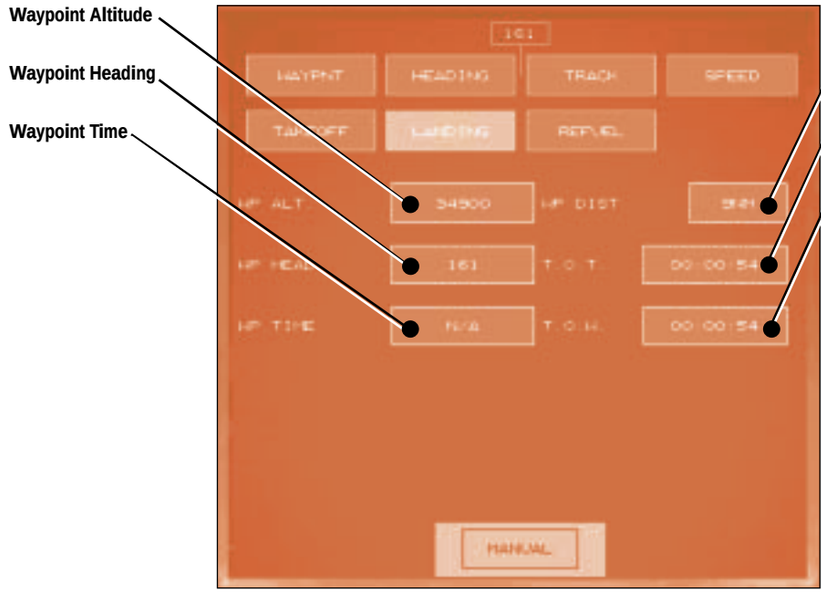
Follow heading - when you need to wander off-route



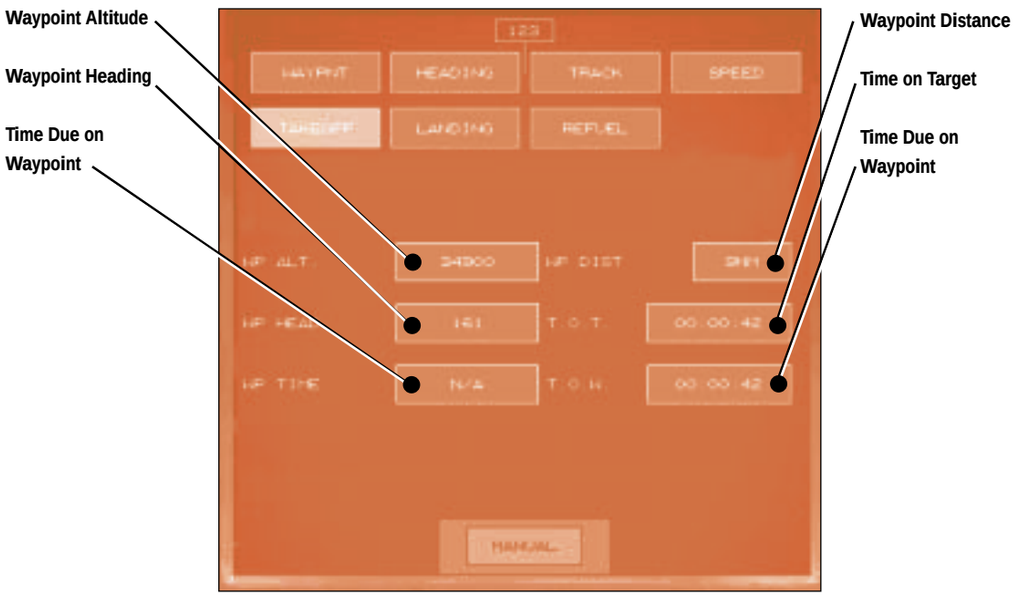
Follow target - attack maneuvering under computer control



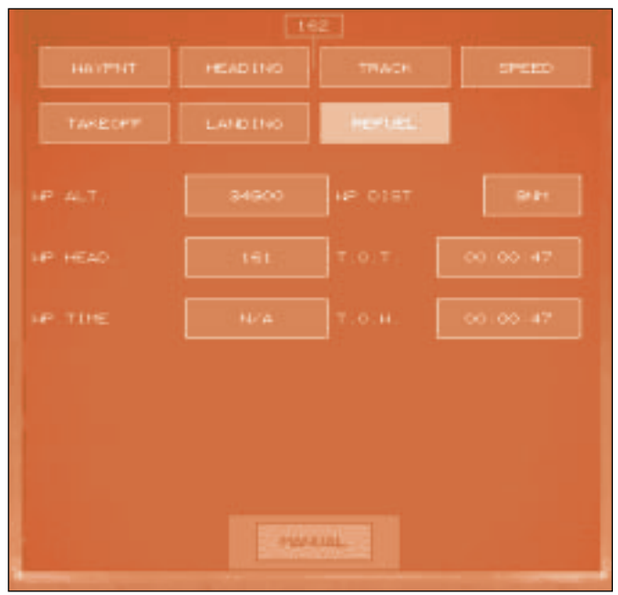
Follow speed - adjust to arrive at targets on time



Landing mode - automated, like modern civil aircraft



Take-off mode - when you have better things to do



Refueling mode - reduce risk in this tricky maneuver

Flight Training

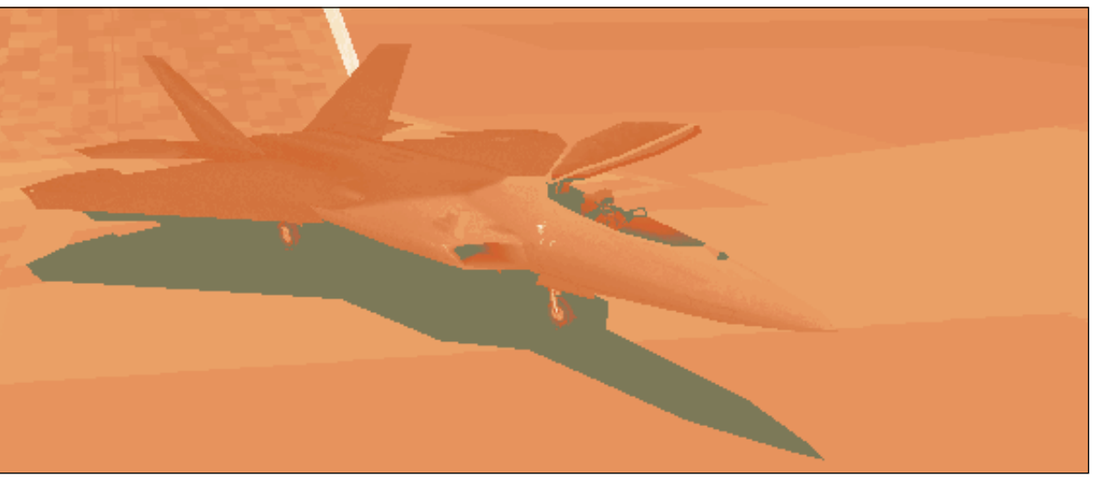
Training is essential if you are to understand the avionics and their application to real missions. In the Training section of Total Air War are missions which should be viewed initially as training.

Engine start

For those in a hurry, start the engines directly by pressing the [(left engine) and] (right engine) symbols on the keyboard. All aircraft systems will power up automatically.

NOTE: the engines will be off and the brakes will be on. The radio frequency will already be set to PUSH 1 for communication with the tower. To select the radio frequency PUSH 1 by pressing 1 on the normal keyboard numbers. To change radio frequencies at any time press the number of the frequency required: 1, 2, 3, 4, from the normal keyboard numbers.

Go to the Systems MFD by pressing 0 on your extended keypad. The MFD will already be displaying the start up screen, press the indicated red start button, when it is green all systems are live and the engines have been started.



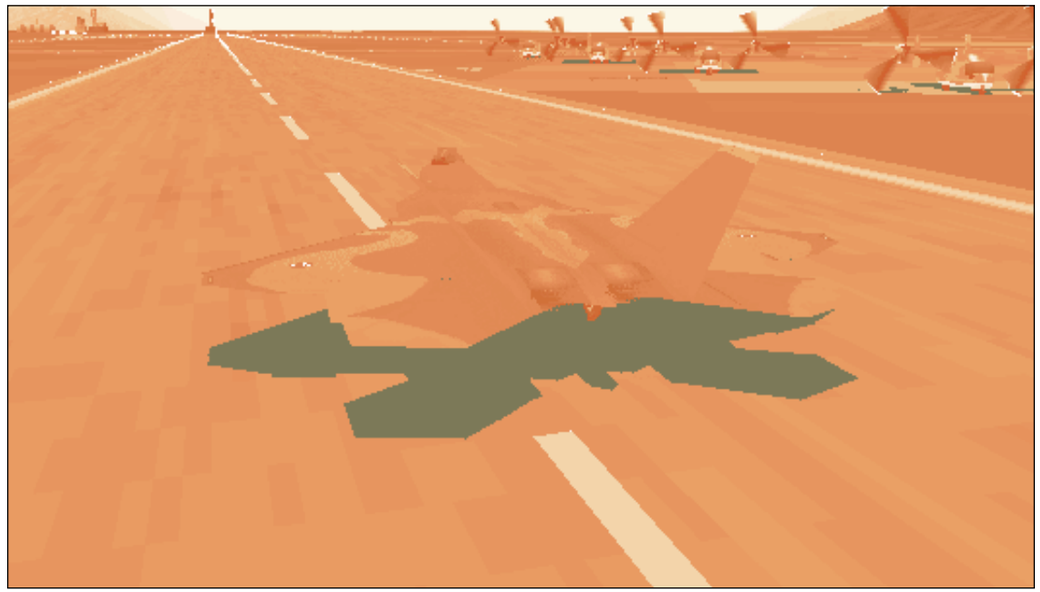
Ready for take-off

When you **start** a new mission on the ground you will find the F-22 Auxiliary Power Unit running and all systems ready for start. The tower will call you for a communications check, *"COMMS CHECK, GO TO NOISECON 5"*. Set your F-22 to (manual) EMCON 5, by pressing E on the keyboard and then option 5, or by pressing the relevant button on the Up Front MFD panel.

For take off select either the ILS, or NAV HUD mode by pressing the H key repeatedly until those HUD modes are displayed.

The canopy will close automatically when you exceed 5 knots and can be closed / opened below that speed by pressing I on the keyboard.

The F-22 – Basic Flight



From a standing start, push throttles to 100%

Taxiing the F-22

The easy way, go to the Systems MFD by pressing 0 on the extended keyboard, press the relevant MFD button to select the Auto-pilot mode on that MFD and then select Take off on the Auto-pilot list of buttons, then engage the Auto-pilot by pressing A on the keyboard. The auto-pilot will now complete all taxiing and take off.

Once your **take off time** has passed the tower will determine a safe time slot for you to begin taxiing. If there is no safe slot, then permission will be delayed. When the tower clears you to taxi, you can move from your parked position. If permission to taxi has not been granted after the communication's check, request your take-off time by picking option 2 Airfield and then choosing option 1, *"SAY MY take-off"* from the menu on the top left of your Helmet Mounted Display. The tower will respond with your take-off time.

Take the brakes off by pressing B on the keypad and increase engine power by repeatedly pressing the extended keyboard + symbol, (or pushing forwards on your throttle). Power will have to be increased to 55% to get the F-22 moving and shortly after throttled back to 53% to maintain a taxi speed of 20 knots. When cornering slow down to around 10 knots.

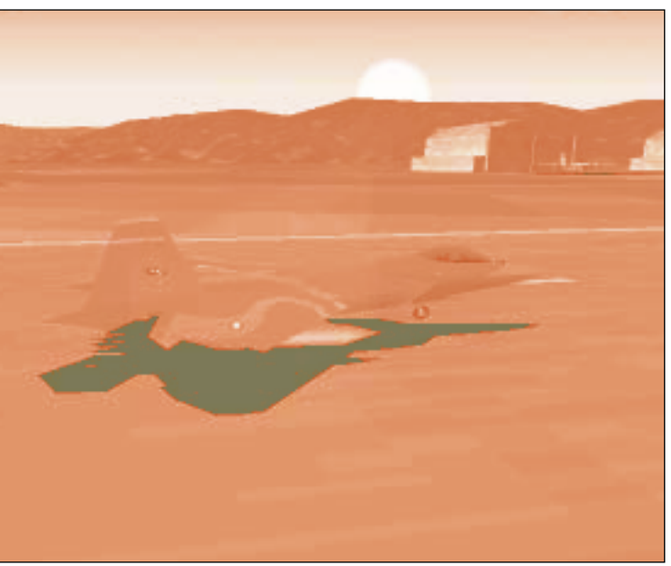
NOTE: exceeding this taxi speed may result in you crashing before you are even off the ground!

The aircraft can be steered on the ground by use of the <, (to the left) and >, (to the right) symbol keys, or by the appropriate use of your rudder pedals. The toe brakes can be actuated to slow one side of the aircraft by pressing SHIFT <, or SHIFT>.

The F-22 – Basic Flight

Unsure where to taxi? then use the way point direction caret (an inverted arrow on the HUD compass ribbon), please see Navigation. The way point direction caret is useful for getting around the airfield. When you arrive at the runway hold area, (the area of taxi way just before the runway), stop by applying the brakes, B on the keyboard and throttle the engines back to ground idle (50%). You will let the tower know you are at the hold automatically, place your F-22 nose just short of the runway edge. Permission to proceed onto the runway *"LINE UP"*, will be given when the runway is clear of other traffic. When you have got the F-22 lined up pointing straight down the runway, then stop.

Remember , do not assume it is always clear, keep a good look out around you. When you are lined up on the runway stop you will automatically declare your readiness to take-off.



Take off speed

Take Off

For those in a hurry, ignore any permissions take the brakes off, increase the throttle to full and pull the F-22 nose off the deck at a speed of 180 knots by pressing the DOWN CURSOR key gently, (or by pulling back on your joystick).

For those in a big hurry, use the DID time skip by pressing SHIFT S to move from your parked position, until you find yourself on the runway. Or press SHIFT S one more time to put you in the air. Refer to take-off permission below.

NOTE: at any time in flight, or on the ground you can stop the action by pressing P to pause the game, (press again to resume).

The easy way, go to the Systems MFD by pressing 0 on the extended keyboard, press the relevant MFD button to select the Auto-pilot mode on that MFD and then select take-off on the Auto-pilot list of buttons, then switch on the Auto-pilot by pressing A on the keyboard.

NOTE: so long as your engines are running, when you select take-off, the Auto-pilot will taxi the aircraft to the runway and take-off.

The tower will give you final **take-off permission** *"YOU ARE CLEARED TO TAKE-OFF"*, Note the altitude you are to climb to and the bearing for airfield departure.

Throttle your engines up to full military power, an indicated 100% on your HUD (the throttles can be snapped to military power by pressing SHIFT + on the keyboard), immediately on reaching that value take the brakes off. When you reach 180 knots pull the nose up by pressing the DOWN CURSOR key gently, (or by pulling back on your joystick). Shortly after leaving the ground bring the gear up by pressing G on the keyboard, keep the aircraft straight, (no rolling) and in a steady 15 degree climb. Climb to the altitude indicated by the tower and steer the aircraft onto the pre-planned route by referring to Navigation.

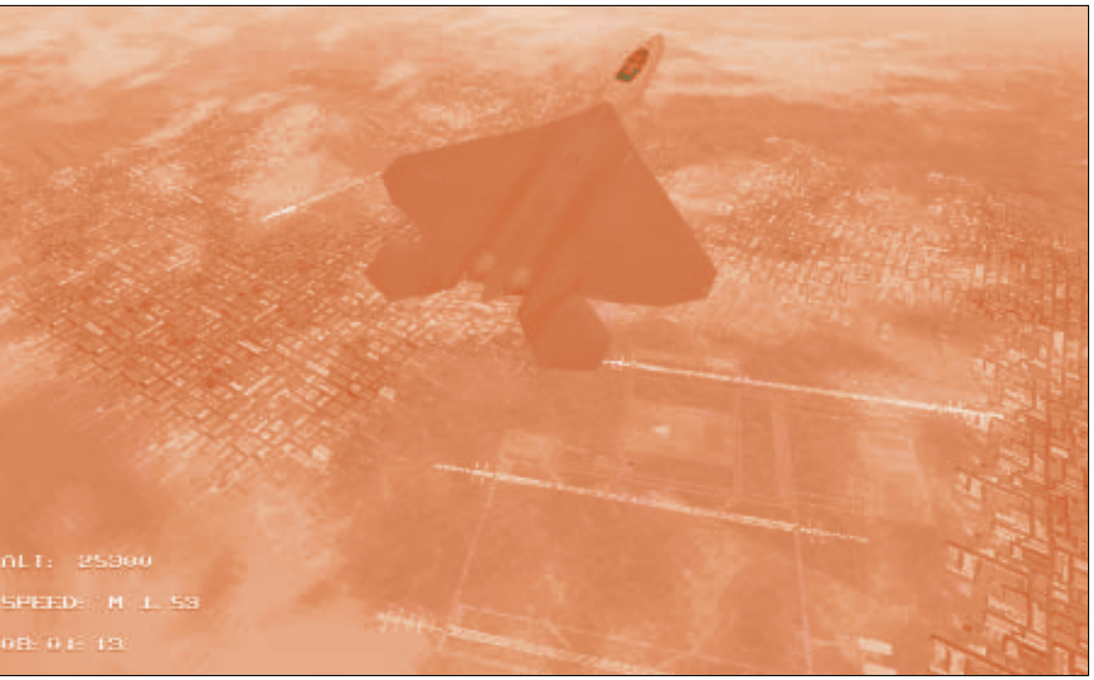
A steep departure from the airfield

The tower will contact you once more *"PUSH 2 FOR MAGIC, GOOD DAY"*, contact the AWACS on radio frequency PUSH 2 (open channel) by pressing 2 on the keyboard, or PUSH VICTOR 3 by pressing 3 on the keyboard and picking option 2 AWACS, then choosing option 7 *"FLIGHT IS AVAILABLE"*, if you intend to fly away from the airfield.

NOTE: from the menu choices now placed in AWACS on your Helmet Mounted Display you will have a choice of requests and reports for the AWACS who will handle all aspects of your flight until you need to contact the tower for landing. If you do not inform the AWACS of your flight you may be interrogated for identification. Please see The AWACS chapter for more information.

NOTE: once you get airborne, turn the aircraft slowly left or right by use of the rudder, press symbol <, >. Or bank for example left and turn by slowly pressing the LEFT CURSOR key, (or pushing the joystick to the left gently.

A much sharper turn can then be executed by pulling the nose up with the DOWN CURSOR key, (or pulling back with the joystick).



Navigation - half the battle is getting there in one piece

Navigation

The **way point direction carets**, will enable you to follow a planned route by looking at the compass ribbon at the top of the HUD. The figure in the center of the box is the compass heading you are currently on. The inverted arrow below the compass ribbon shows where you must steer the box in order to line up with the first way point on your route.

The triple vertical line symbol above the compass ribbon shows where you must steer in order to intersect the line between the last way point and the next.

NOTE: these navigation symbols are displayed in all HUD modes. The symbols will also indicate a direction to follow for the right taxi way to reach the correct end of the runway as indicated by the tower.

The navigation HUD can be selected by pressing the H key repeatedly until NAV HUD appears. The NAV HUD will tell you if you are high / low, or early / late on your intended route and so will help you to judge what you should do in order to follow your mission correctly.

Please see the Navigation HUD illustration in Head Up Display.

The F-22 – Basic Flight

Heading for home!

Preparing to Land

For landing you must have sought and been granted permission to land. The auto-pilot, if used must be in landing mode.

For those in a hurry, use the DID time skip by pressing SHIFT S until you find yourself in a parking position.

For those in a desperate hurry, press SHIFT Q and finish the game!

The easy way, you must be within 15 miles of the airfield and gain permission to land by selecting radio frequency PUSH 1, select it by pressing 1 on the keyboard. Request permission to approach from the tower by picking option 2 Airfield and then choosing either option 3, *"DIRECT APPROACH"* (or option 5 *"CIRCUIT APPROACH"* from the menu on the top left of your Helmet Mounted Display. Go to the Systems MFD by pressing 0 on the extended keyboard, press the relevant MFD button to select the Auto-pilot mode on that MFD and then select landing on the Auto-pilot list of buttons, then engage the Auto-pilot by pressing A on the keyboard.

NOTE: the Auto-pilot will land the F-22 and taxi it back to a parking slot, all necessary messages and steps will be handled automatically. You will only be responsible for engine shut down once parked.

The F-22 – Basic Flight

When you need to return to an airfield it will be for one of four reasons:

1. You are following your pre-planned route.
2. You have requested a vector for recovery at your mission start base.
3. You have requested a divert airfield from the AWACS.
4. You intend to land at an airfield of your choice.

NOTE: at 15 miles from the base you will be able to see the landing light pattern and the ILS hoops on your ILS HUD only if you are within a few degrees of the glide slope at the end of the runway. Only the runway to be used will display open ILS hoops.

Pre planned landing

As you get to 15 miles of your destination airfield on your way point route select the ILS HUD mode and radio frequency PUSH 1 by pressing 1 on the keyboard. Request permission for recovery from the tower by picking option 2 Airfield, then choosing either of options 3 (*"DIRECT APPROACH"*), 4 (*"TEARDROP APPROACH"*) or 5 (*"CIRCUIT APPROACH"*) from the menu on the top left of your Helmet Mounted Display, then refer to Landing below.

Vector for Recovery

In order to assist with navigation to your destination airfield, select radio frequency PUSH 1 and the ILS HUD mode, then request a vector for recovery from the tower by picking option 2 Airfield, then choosing option 2, *"VECTOR FOR RECOVERY"* from the menu on the top left of your Helmet Mounted Display. You will be given a direction to the airfield.

Requesting a divert airfield

To request a divert airfield from the AWACS who is controlling your flight first ensure you are in radio frequency PUSH 2, or PUSH VICTOR 3 by pressing 2 or 3 on your keyboard.

From the menu on the top left of your Helmet Mounted Display, pick option 2 AWACS, then choose option 1 *"REQUEST DIVERT AIRBASE"*. The AWACS will name the nearest available airfield, give you a direction to it and its range from you. Then refer to 'Land' at an airfield of choice.

NOTE: requesting any information from the AWACS when an AWACS is not present, will obviously meet with silence!

Land at an airfield of choice

When you are within 15 miles of any airfield you can land there by selecting the ILS HUD mode and radio frequency PUSH 1, then request permission for approach from the tower by picking option 2 Airfield, followed by either of options 3 (*"DIRECT APPROACH"*), 4 (*"TEARDROP APPROACH"*) or 5 (*"CIRCUIT APPROACH"*) from the menu on the top left of your Helmet Mounted Display, then refer to Landing below.

Gear down for finals

Landing

The ILS HUD is necessary for landing information and can be selected by pressing the H key repeatedly until the ILS HUD appears. This HUD mode indicates a series of glide slope markers visible rising from the end of the runway, these indicate the correct path to follow for touchdown. The ILS markers can be turned on / off while in the ILS HUD mode by pressing the appropriate button on the Systems MFD.

For additional information please see the Instrument Landing System HUD illustration in Head Up Display and the Systems MFD illustration in Multi Function Displays.

NOTE: to talk to the tower and hear instructions you will need to be on radio frequency PUSH 1, select it by pressing 1 on the normal keyboard numbers. The way point and way point path markers mentioned in Navigation are of great use in all kinds of approaches to indicate where you should fly to next.

Your airfield approach will be one of the following:

- Circuit approach
- Teardrop approach
- Direct approach

The normal approach is Circuit which the tower will advise you of with the message: *"JOIN THE LEFT CIRCUIT, FOR RECOVERY ON RUNWAY"*, plus the runways number,

Teardrop approaches for airfields under threat

when you are within 15 miles of the runway. If you specifically request a teardrop, or straight in approach you will receive clearance for that kind of approach, or you may be refused due to traffic considerations.

NOTE: you can acknowledge the towers orders by pressing Y on the keyboard.

Circuit approach

This is the normal fighter approach to a military airfield. It is performed by making an approach directly for the runway to be landed on and descending to an altitude of 3,000 feet by the time you are directly over the runway. You must fly down the length of the runway maintaining that altitude and follow the left hand circuit. The circuit will be indicated on your Situation MFD as an extension of your way point route and will further be indicated by way point direction carets. *Please see Navigation for more details.*

The circuit is approximately 2.5 miles across and 3 miles along the runway side. Turn left onto leg 2 and at the next indicated turn onto leg 3 which is the back leg, descending to 1,500 feet. Lower your undercarriage by pressing G on the keyboard. Continue to the next turn and onto leg 4, here you should be able to see the ILS hoops as you are about to intercept the glide path. Turn onto leg 5 for final approach, notify the tower by selecting radio frequency PUSH 1 and notify the tower that you are on finals by picking option 2 Airfield. Then choose option 6 '*FINALS*' from the airfield menu, then descend on the glide slope. The tower will respond by saying *'CLEAR TO LAND'* if the runway is clear or '*LANDING NEGATIVE, GO AROUND*' if another flight is taking off or is ahead of you on the

Direct landing approach with no circuits

Instrument Landing System.

For additional information please refer to Final approach below.

Teardrop approach

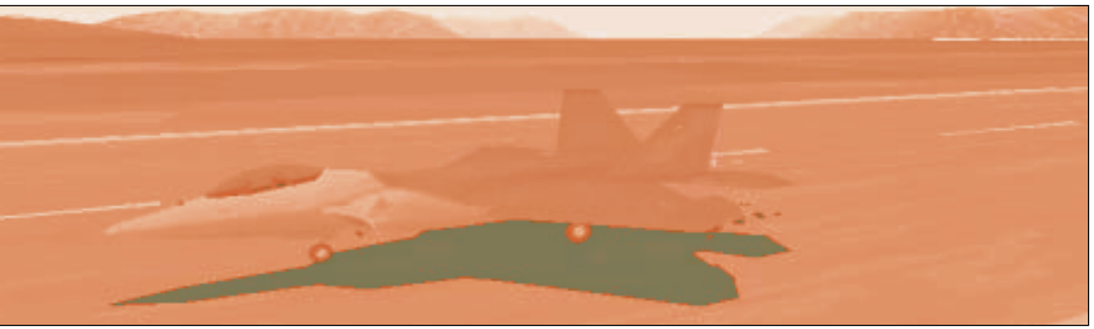
The Teardrop approach is used specifically at front line airfields that might come under attack at short notice and is essentially a much shorter and tighter version of the Circuit approach. Teardrop approach is a dynamic maneuver which rapidly reduces a high approach speed and altitude by pulling a high G spiraling turn to quickly land and reduces the risk of attack by enemy surface to air missiles, if the airbase is close to enemy forces.

To request a Teardrop approach you should already be in radio frequency PUSH 1, pick option 2 Airfield, then choose option 4, *"TEARDROP APPROACH"* while you are within 15 miles of the runway. Approach the glide slope approximately half way along its length as indicated on the ILS HUD by the ILS hoops. As you intercept the glide slope you need to be at 1500 feet, notify the tower by selecting radio frequency PUSH 1, pick option 2 Airfield, then choose option 6 '*FINALS*' from the airfield menu, spiral sharply round 360 degrees so that you lose height rapidly to approximately 500 feet and pointing towards the runway.

For additional information please refer to Final approach below.

Direct approach

The traditional straight in approach to the runway. To request a Direct approach you



No brake-chute! Air-brake rudders and wheel brakes slow you down

should already be in radio frequency PUSH 1, pick option 2 Airfield, then choose option 3 *"DIRECT APPROACH"* from the menu on the top left of your Helmet Mounted Display while you are within 15 miles of the runway. When permission is granted work your F-22 around to the correct runway so that you can make the most direct approach and see the runway lighting and ILS hoops as soon as possible. As you intercept the glide slope notify the tower by selecting radio frequency PUSH 1, pick option 2 Airfield, then choose option 6 *'FINALS'* from the airfield menu.

Final Approach

The Glide Slope

The glide slope is indicated by the ILS markers projecting out of the end of the runway. You must intercept the glide slope allowing yourself enough room to line up with the runway.

Steadily reduce your **airfield approach speed** to **230 knots** by repeatedly pressing the extended keyboard - key, (or by pulling back on your throttle) by the time you have intercepted the glide path, your **glide slope speed** should be **170 knots**, **power setting 57%**. You must get the F-22 pointed straight down the approach and runway and level the wings. It may help to deploy the air-brakes by pressing B on the keyboard. If your undercarriage is not already down, lower it by pressing G on your keyboard.

While on your final approach it is important to notify the tower by selecting radio frequency PUSH 1, pick option 2 Airfield, then choose option 6 "FINALS" from the airfield menu. This action will allow the tower to free up the runway once you have landed and will give them a final chance to grant permission or direct you to go around the circuit once more.

Keep the velocity vector in the HUD just beyond the touchdown 3, 2, 1 markers on the runway, when your altitude is 50 feet, pull the nose up slightly so that the velocity vector is approximately half way down the runway. Reducing the power to 55% (flight idle), at this point may help your touchdown.

NOTE: on touch down the wheel brakes will be applied already if you have deployed the air-brakes, to take the brakes off press the B key on the keyboard. You will get the shortest possible landing if you leave the brakes on.

The F-22 – Basic Flight

NOTE: the F-22 is not equipped with a braking chute, or thrust reversing.

Once you have achieved taxiing speed of 20 knots or less, the tower will notify you where to park your F-22. You will be able to find your way back to your allotted parking space by use of direction carets at the top of all HUD displays.

For additional information please see Navigation above.

NOTE: once back on the runway, the F-22 will be rearmed / refueled automatically

Permission to land is refused!

When the airfield is busy , or out of action you may be given other instructions. If the airfield is out of action, you will be told that the *"THE AIRBASE IS BLACK, DIVERT TO..."*, plus the divert airfield name. Your way point route will be automatically extended to the new airfield, as portrayed on the Situation MFD.
At a busy airfield you may be directed to turn to a new heading, or to *"JOIN THE STACK"* at an indicated altitude. The Stack is a circuit for aircraft to orbit within, where the aircraft start at the top and spiral slowly down until they are given permission to land, the position will be the same as the landing circuit in this game, the rotation is left hand (anti-clockwise seen from above) like the landing circuit.

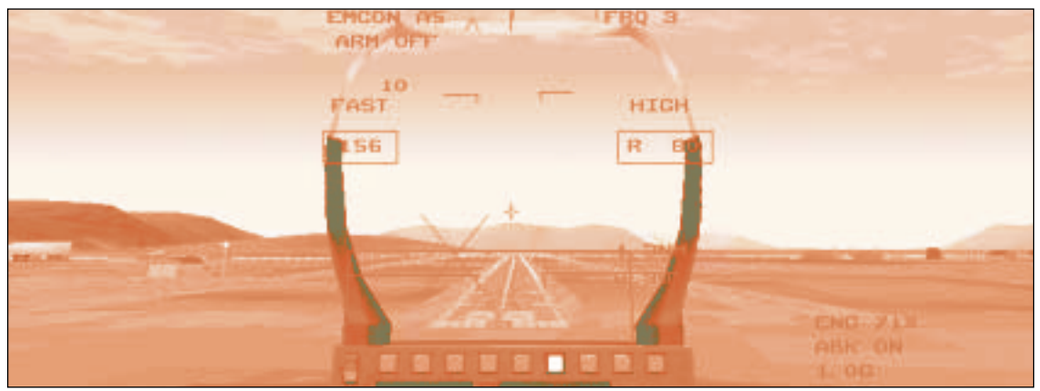
When the player is on final approach, (i.e. on the glide slope) final permission may be refused with the message: *"LANDING NEGATIVE, GO AROUND"*. In this case you must follow the landing circuit at 1,500 feet altitude one more time and attempt a landing when you are on leg 5, descending on the glide slope as in Direct Approach.

Landing at Friendly airfields to rearm and refuel

You can land at friendly airfields to rearm and refuel your plane. Land as normal on the runway, bring your plane to a halt and you will be rearmed and refueled.

Emergency Landings

If your aircraft has damaged under carriage you may have to perform an emergency 'belly' landing. For safety reasons we recommend jettisoning all stores before attempting a belly landing.



Touchdown! Note the ILS markers and the position of the velocity vector

Air Refueling

The United States Air Force is alone in using the flying boom method of aerial refueling, as opposed to the basket method favored by all other air forces. When an aerial refueling has been planned into your route, the refueling point will be marked on your Situation MFD and the patrol route of the tanker you must refuel from will also be visible.

The Refueling HUD can be selected by pressing the H key repeatedly until the REF HUD appears. The Refuel HUD indicates information vital for refueling correctly.

Please see the Refueling HUD illustration in Head Up Display.

NOTE: your tanker will display white anti collision strobe lights at the tip of its fin and underneath the center fuselage, plus flashing red / white beacon lights above and below the fuselage. You should acknowledge the refuelers messages by pressing Y on the keyboard.

The easy way, refer to 'vector to the nearest refueling aircraft' below. You must approach the tanker at an altitude 10,000 feet above the tanker. When you are within 15 miles of the tanker change your radio frequency to PUSH VICTOR 4 by pressing 4 on the keyboard, then you must request permission to refuel from the tanker by picking option 2 Refueler and then choosing option 2 *"REFUEL PERMISSION"* from the menu on the top left of your Helmet Mounted Display.

The tanker will tell you to *"SKIP IT"* if refueling is not currently possible, or will give you permission by replying *"AFFIRMATIVE, WEAPONS AND NOSE COLD"*. **You must reply by pressing Y** on the keyboard, in order for the auto-pilot to work. Ensure that your radar output is reduced by going to manual EMCON 2.

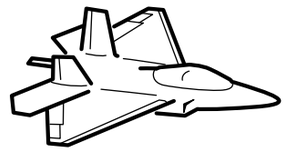
When the refueler says *"CLEARED, PRE CONTACT"*, you can engage the auto-pilot. Go to the Systems MFD by pressing 0 on the extended keyboard, press the relevant MFD button to select Auto-pilot mode on that MFD and then select refueling on the Auto-pilot list of buttons, then engage the Auto-pilot by pressing A on the keyboard.

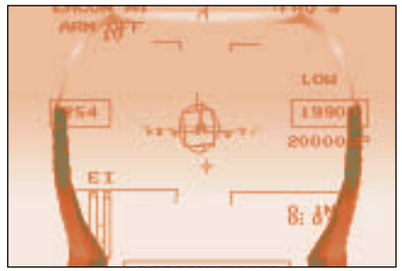
The auto-pilot will handle the refueling from now on and will switch off automatically once the refuel boom is connected.

Please refer to 'refueling is complete'.

Manual refueling, should you need to refuel when no refueling has been scheduled, you can request a vector to the nearest refueling aircraft by selecting radio frequency PUSH 2 or PUSH VICTOR 3, (2 or 3 on your keyboard), pick option 2 AWACS and then choose option 2 *"VECTOR TO TANKER"* from the menu on the top left of your Helmet Mounted Display. You will be given the necessary vector and told to contact the indicated tanker on radio frequency PUSH VICTOR 4, (4 on your keyboard).

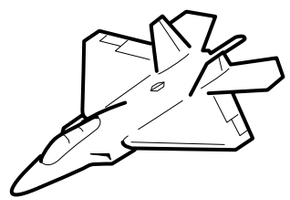
The F-22 – Refueling





The gas station in the sky

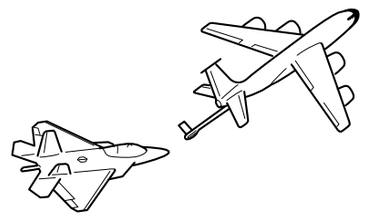
You must approach the tanker at an altitude 10,000 feet above the tanker. When you are within 15 miles of the tanker change your radio frequency to PUSH VICTOR 4 by pressing 4 on the keyboard, then you must request permission to refuel from the tanker by picking option 2 Refueler and then choosing option 2 *"REFUEL PERMISSION"* from the menu on the top left of your Helmet Mounted Display.



On the way to a top-up. All major credit cards accepted

The tanker will tell you to *"SKIP IT"* if refueling is not currently possible, or will give you permission by replying *"AFFIRMATIVE, WEAPONS AND NOSE COLD"*. Reply by pressing Y on the keyboard. You must ensure that your radar output is reduced by going to manual EMCON 2. (Or manual EMCON 1, if your mission requires stealth). Close the refueler to approximately one quarter of a mile and slightly below his altitude.

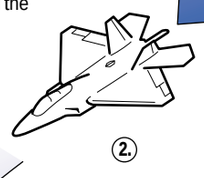
NOTE: if you are in manual EMCON 1 you will be able to do a stealthy refuel. The refueler will not speak to you if you are in EMCON 1 you must use your judgement and the Receiver Director Lights for position information. When the boom is connected a wired voice link will be made enabling you to hear the boom operator's *"CONTACT"* and *"DISCONNECT"* messages.



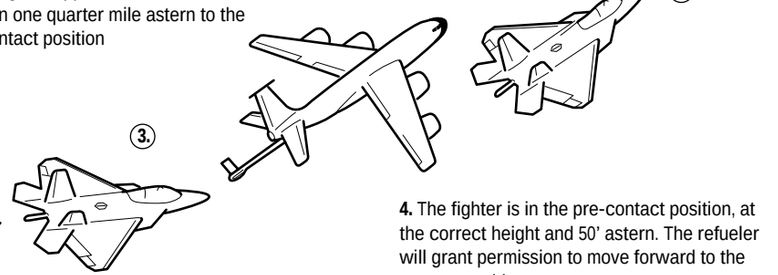
The F-22 – Refueling

Air-to-Air Refueling

1. The fighter has a vector to the tanker aircraft



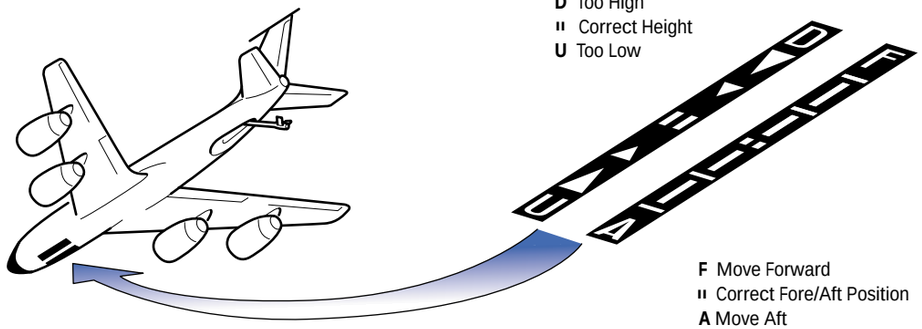
2. The fighter requests permission to refuel from the tanker. Once permission is granted the approach is made from above the tanker's altitude

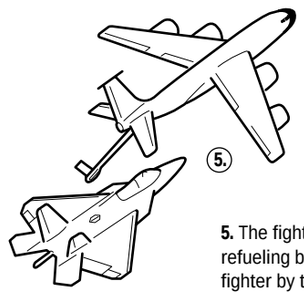


3. The fighter approaches the tanker, from a position one quarter mile astern to the pre-contact position

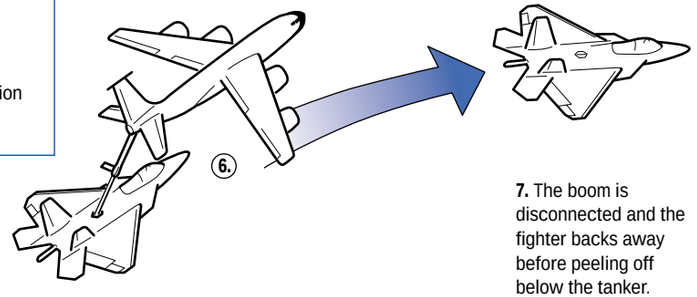
4. The fighter is in the pre-contact position, at the correct height and 50' astern. The refueler will grant permission to move forward to the contact position.

The Receiver Director Lights





5. The fighter is in the contact position. The refueling boom will be 'flown' into the fighter by the refual boom operator.



6. The boom has made contact and fuel flows.

7. The boom is disconnected and the fighter backs away before peeling off below the tanker.

The Refueling Boom

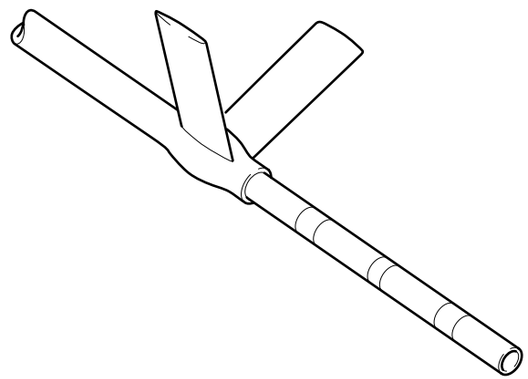
The refueling boom is telescopic and has colored bands marking how far it is extended.

Too compressed, marked by a wide yellow band.

The 'green zone'.

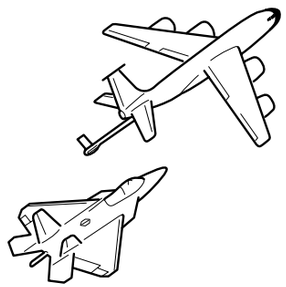
Optimum position marked by a narrow yellow band.

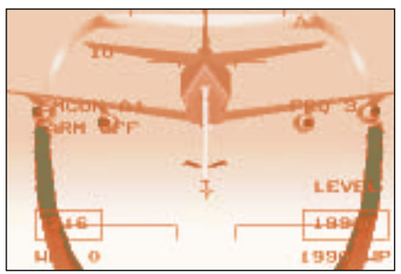
Too extended, marked by a wide yellow band.



Aim to arrive in the pre-contact position

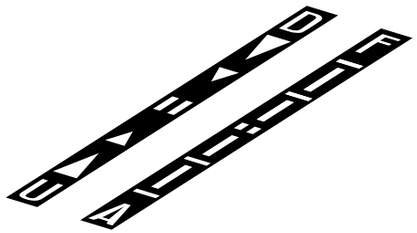
Work your F-22 in behind the refueler, approximately twenty feet below his altitude. When you are within 100 feet behind, the refueler will give the message *"CLEARED, PRE CONTACT"*, which means you must go to the pre-contact position fifty feet behind the tanker refuel position.





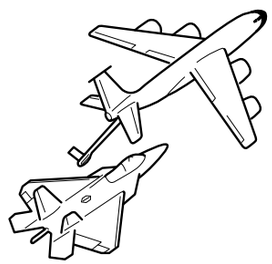
Gentle use of the throttle and stick is required

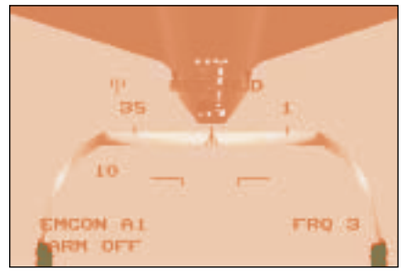
When you are at the pre-contact position the refueler will give you the message *"CLEARED CONTACT"*. This means that you are at the right level below the refueler and fifty feet behind the tanker refuel position. The tanker will turn off his lower strobe light and both upper and lower beacons will flash red only, to indicate he is now 'engaged'. You must now go slowly forward to the contact position. To help you achieve this the refueler displays two patterns of lights called the Receiver Director lights under its forward fuselage.



The receiver director lights

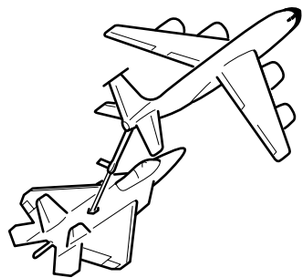
From your position the lights on the left indicate if you are high or low of the contact position, Up and Down letter cues will also display at the apparent top or bottom of the left director lights. The right hand lights indicate the your current forward / aft location of the contact position. Forward and Aft letter cues also display at the apparent top or bottom of the right director lights.





About to receive the boom

When you are in the correct position the refueler will give the message *"STABILIZE"*. You must now hold station with the refueler, he will fly the refueling boom into the receptacle on the upper fuselage of your F-22. When the boom makes contact he will give the message *"CONTACT"*, you will automatically acknowledge the boom operator by saying *"AFFIRM"*.



When you refuel, so do your buddies

The Receiver Director Lights will now be controlled by the boom position and will help you to maintain your position within the bounds of permissible movement of the refueling boom. The extending part of the boom has a series of colored bands on it, when the narrow yellow stripe of the extending part of the boom is against the lowering part of the boom you are in the right forward / aft location of the contact position.

The boom connects behind you

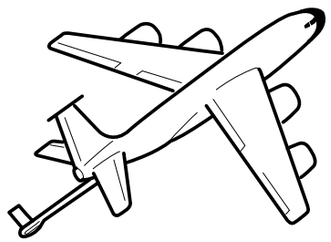
Refueling is complete

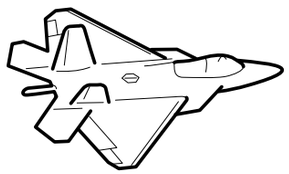
When your refueling is complete the refueler will give you the message *"DISCONNECT AND PUSH 2"*, he will then disconnect the boom from your aircraft, **you must break the connection by throttling back** your engines slightly, by pressing the - key on the keyboard. If you are refueling on your own you are now clear to recommence your mission.

As the boom moves clear, slowly back your F-22 away. It is customary to leave the refueler after first backing well clear by reducing altitude and pulling away towards the right before returning to your mission heading 5,000 feet below the refueler so as to reduce possible collisions with other aircraft waiting to refuel.

If you are refueling with your wingman, after backing slowly away you must wait for your wingman by swinging out to trail the starboard (right) wing tip of the refueler.

Once the refueling is complete you must follow the refueler's request and change your radio frequency to PUSH 2, or PUSH VICTOR 3, by pressing 2, or 3 on the keyboard. contact the AWACS and let them know that you are now available again by choosing option 2 AWACS and then option 7 *"FLIGHT IS AVAILABLE"*.





Rearming and Refueling

When you land on the runway the F-22 will automatically be rearmed / refueled with the loadout that was originally present.

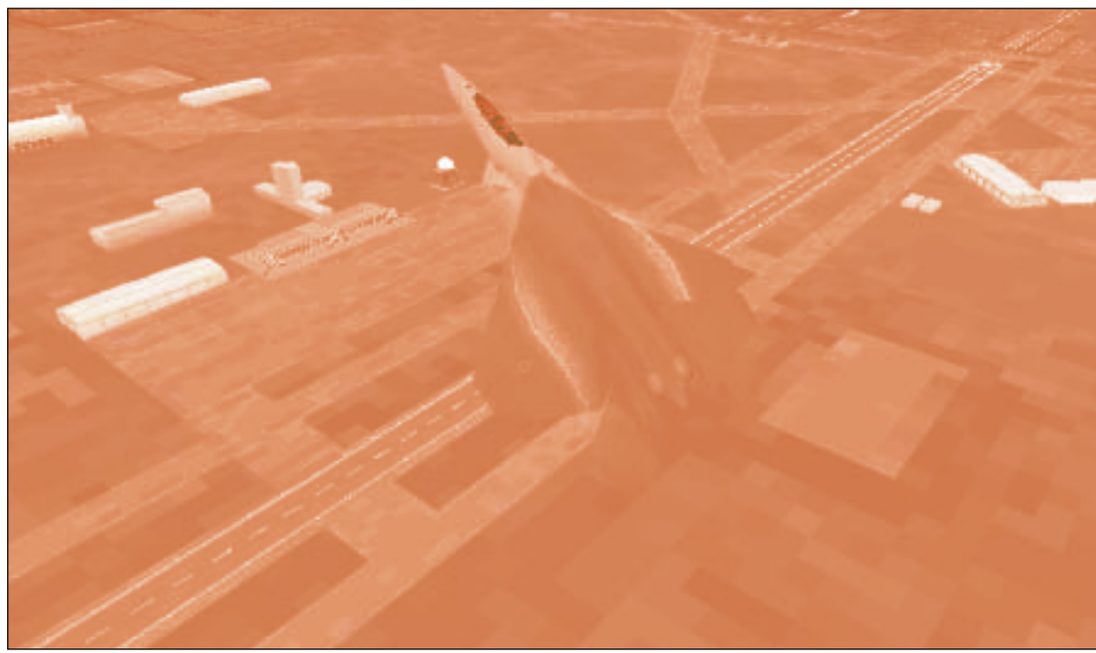
Thrust Vectored Maneuvers

The F-22 enjoys the extra maneuverability of thrust vectored engines which apart from giving quicker responses for dogfighting, will also allow very high angles of attack, (nose up angle, towards the direction of flight). This type of control is of particular relevance at speeds where aerodynamic lift and influence are low. The F-22, Sukhoi Su-37 and Mikoyan MiG-35 are all able to use thrust vectoring to aim the fighter towards an enemy briefly while flying in another direction.

Within the Total Air War sim, the F-22 has not been modeled with thrust vectoring engaged all the time as in the real F-22. To help you get to grips with it DID has opted to allow the user the ability to pick when he wants thrust vectoring by pressing and holding the KEY ABOVE TAB, to disengage simply let go of the key. By not having thrust vectoring engaged permanently the user will be able to make greater use of both the expanded and normal flight envelope.

The F-22 flight control systems prevents the pilot from overloading the aircraft. The effect of thrust vectoring is reduced with increasing speed and will be only really be noticeable below 400 knots airspeed.

For additional information please refer to the Training section of Total Air War and the Online help (main menu, help button), for more information on thrust vectored flight, how to use it, and of course try it out in one of your early missions.



It's not only the Russians who pull high-alpha stunts like these!

Weapons Training

In the Training section of Total Air War are a series of missions which should be viewed as training missions. The Missions are written so that each contains more than the aircraft, and targets necessary to learn the specific lesson.

Difficulty Levels

The difficulty of the game can be set in the game options screen. The three difficulty options determine the accuracy of weapons fired against your aircraft, the accuracy of your guided weapons and the amount of damage taken by your F-22 when hit. For additional details, please refer to the Training section of Total Air War, and the Online help (main menu, help button), for more information on weapons, and how to use them.

Air-to-Air Combat

Air-to-air combat is made up of five stages:

1. Detection
2. Beyond Visual Range Combat
3. Closing
4. Maneuvering or Dogfight
5. Disengagement

Detection

In detection it is often the case that he who sees first wins, by electronic or visual means. As you will have seen from the Avionics section the F-22 is able to get information about potential enemies from great ranges, and can operate completely stealthily while receiving data from an AWACS or another F-22.

Cued for the kill. Four enemy aircraft in AWACS

Cued for the kill. The same four enemy aircraft in the F-22 cockpit

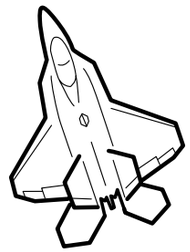
Missile range

Missiles in general will have a greater range when launched at a higher altitude, or a higher flight speed.For the purposes of this manual a benchmark 'best range' has been quoted, which represents an optimum launch range. In some circumstances this may not be achieved, or may be exceeded, depending on the individual circumstances.

NOTE: weapon performance has in some cases been altered to benefit game playability.

BVR combat

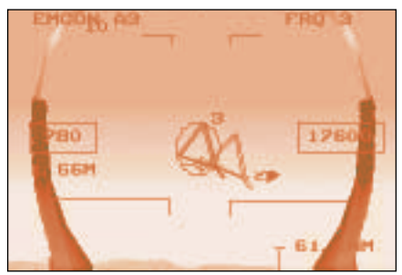
From combat experience many fighter pilots will be able to tell you that four out of five victories are achieved in BVR combat. Achieving an attacking position undetected and then launching a surprise attack while being vigilant of enemy surprises is of great importance.*Please refer to the Introduction*



of this F-22 aircraft chapter to see how the F-22 has been designed to be particularly suited to the BVR air combat role.

The United States Air Force uses a tactic called the 'Grinder', a technique that maximizes the chances of success in attacking an opposing force, especially if that force is superior in numbers.

Please refer to Air to Air Combat Tactics below.



Beyond Visual Range combat - made easy

Please refer to the Training section of Total Air War, the Weapons Training BVR AMRAAM mission teaches you about detection of targets, and engaging those targets in BVR combat.

The AIM-120 AMRAAM

The AIM-120R AMRAAM is a long range radar guided ram jet powered version of the standard AMRAAM missile. It has a best range of 44 miles and uses its ramjet power to close a target very rapidly, thereby reducing the chances of a target maneuvering out of its way.

The AIM-120C AMRAAM has a best range of 31 miles and is powered by a slower flying rocket motor.

To launch an AMRAAM you must have the Air-to-Air HUD selected by pressing RETURN on the keyboard, this will also select air to air weapons. Keep pressing RETURN until the HUD weapon indicator shows you have selected the AMRAAM of your choice. Both versions of the AMRAAM missile are cued to their target by the F-22's avionics. On the way to the target the missiles own radar takes over and acquire the target, making the AMRAAM a `fire and forget missile'.

AMRAAMs can be cued by radar, IRST, or off board information.

NOTE: if the user launches an AMRAAM at manual EMCON 1 no radar cuing will be possible.

If an AWACS, or another F-22 (data sharing), is not present then no cuing from off board sensors is possible.

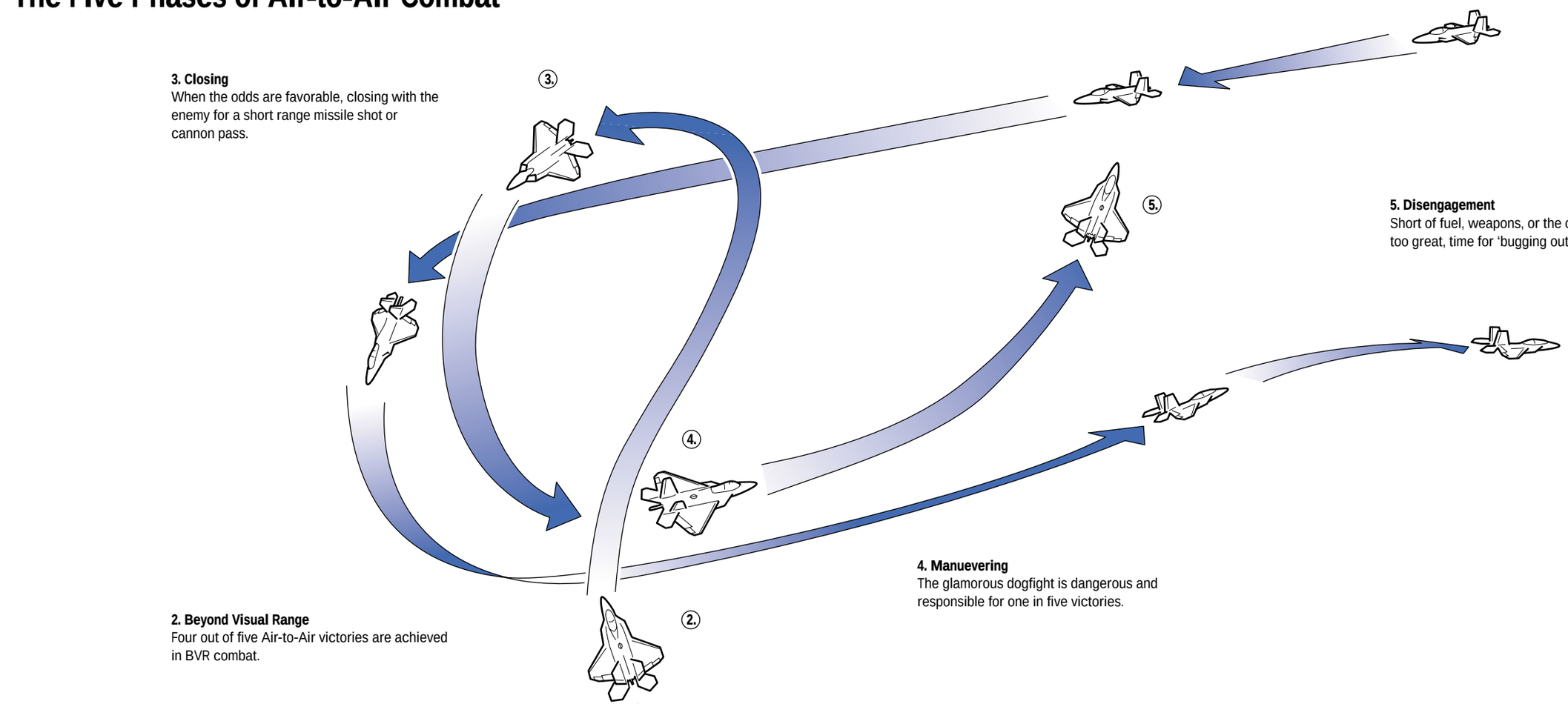
A target is often able to cover a lot of sky between missile launch and half distance. It is therefore possible that the missile may arrive at half the distance, and not be able to find the target in the position that the F-22 predicted! especially if the target realizes it is under attack and maneuvers hard. The F-22 pilot can sometimes ensure a higher probability of a kill against a target that he

continued on page 118

The F-22 – Air-to-Air Combat

The Five Phases of Air-to-Air Combat

3. Closing
When the odds are favorable, closing with the enemy for a short range missile shot or cannon pass.



5. Disengagement
Short of fuel, weapons, or the odds have become too great, time for 'bugging out'.

4. Manuevering
The glamorous dogfight is dangerous and responsible for one in five victories.

2. Beyond Visual Range
Four out of five Air-to-Air victories are achieved in BVR combat.

1. Detection
It is essential to locate the enemy first and maneuver to a firing position.

The F-22 is designed to detect the enemy first, by use of its stealth and avionics design.

AMRAAMs can be launched while the enemy aircraft is still unaware that it is under attack. These abilities make the F-22 ideal for suprise attacks or use of the 'Grinder'.

Once in a dogfight, thrust vectoring and an advanced helmet display give the F-22 pilot the 'edge'.

The F-22 – Air-to-Air Combat

continued from page 115

suspects may maneuver by keeping his nose pointed towards the target.

Potential targets must be entered into the Shoot list, (one Shoot list is made for each kind of weapon).

Please refer to Shoot lists, in the Avionics section.

The targets will be marked in the HUD, Attack, Situation, and Defense MFDs. The first to be fired at is marked in a special way, please see the Head Up Display, and Multi Function Display sections and refer to the Target Marking diagrams in each of those sections.

NOTE: both the HUD and Attack MFDs display data on missile range.

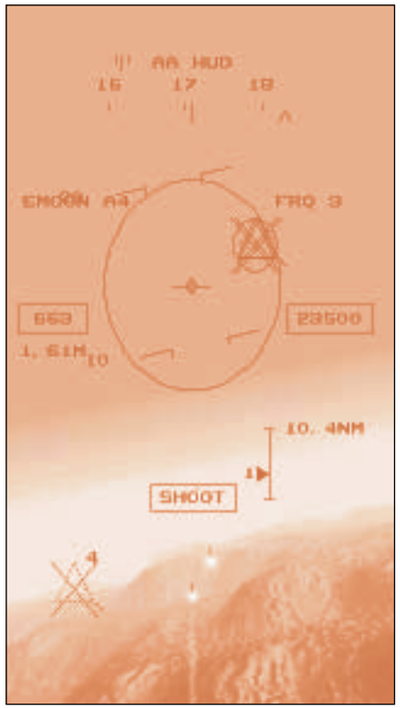
Please refer to the Head Up Display, and Multi Function Display sections.

On the Air to Air HUD, and on the Attack display you will find the missile steering circle and steering dot.

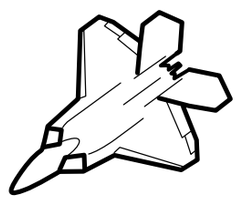
The missile steering circle reflects the probability of kill, (also expressed on the HUD as a 00% pk value), i.e. the bigger the circle is portrayed the greater the chances of killing the target if the missile is launched at that moment.

The missile steering dot indicates where you ought to be aiming your nose in order to close the target.

The word “SHOOT” will appear on the HUD, and Attack displays if the AMRAAM is within range (parameters) of the target. Pressing the SPACE bar will launch an external weapon, or open the main bay doors briefly and launch an internally carried weapon.

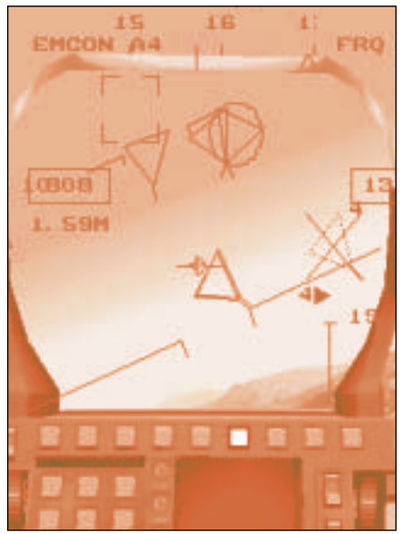


AMRAAM away. Note the HUD symbology



Closing

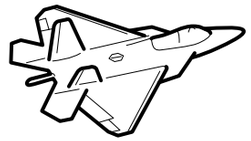
As the range continues to reduce you may not have destroyed all the targets, or be out of AMRAAMs, your next task will be to rapidly close the distance between you while setting up your ideal Sidewinder firing solution.



One versus many is now a fight loaded to the F-22’s advantage

Maneuvering

Maneuvering, or dog fighting has long been the most glamorous part of air combat but is in fact responsible for only one fifth of all air combat victories. This part of combat is highly dangerous with a high loss rate, like BVR combat he who can fire his short range missiles will usually gain the advantage, but if you fail to hit the target in the opening part of the dogfight, the victory will go to the most experienced pilot making best use of the most maneuverable fighter.

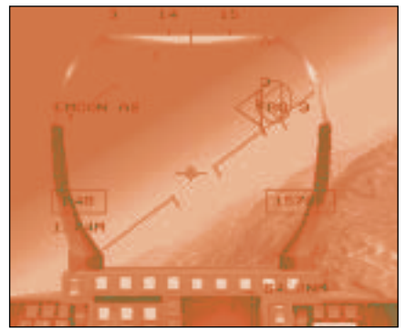


Please refer to the Training section of Total Air War, the Weapons Training DOGFIGHT SIDEWINDER mission continues on from the BVR mission, and teaches you to first close and then engage the enemy with firstly the Sidewinder missile, and then your gun in dogfighting combat.

The AIM-9x Sidewinder

The AIM-9x Sidewinder is a short range, thrust vectoring, Infra Red, (heat) guided missile with at best a range of 10 miles. As the missile is only cued in the direction of the target, and once launched relies on it IR. seeker, it is truly a fire and forget weapon.

To launch a Sidewinder you must have the Air to Air HUD selected by pressing RETURN on the keyboard. This will also select air to



AIM-9X is an extremely effective, off-boresite missile

The F-22 – Air-to-Air Combat

air weapons. Keep pressing RETURN until the HUD weapon indicator shows you have selected the Sidewinder.

The Sidewinder is cued to its target by the F-22's IRST primarily, or by cuing with the helmet mounted sight. It can also acquire a target by being put into the airstream and pointed in the general direction of the target, by pointing the F-22 at it!

The Sidewinder can have targets designated in the same way as the AMRAAM, i.e. automatic or MFD manual entry in a shoot list. Potential targets must be entered into the shoot list, (one Shoot list is made for each kind of weapon).

Please refer to Shoot lists, in the Avionics section.

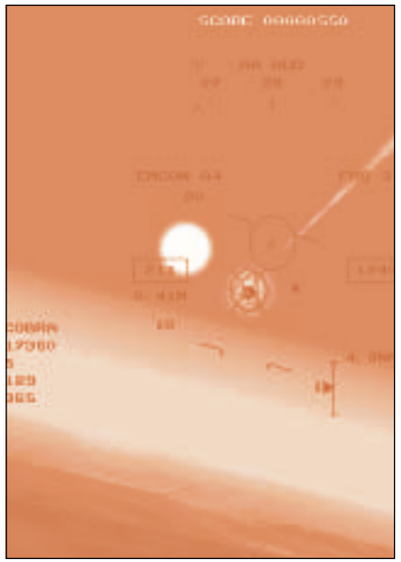
The targets will be marked in the HUD, Attack, Situation, and Defense MFDs, the first to be fired at is marked in a special way.

Please see the Head Up Display, and Multi Function Display sections and refer to the Target Marking diagrams in each of those sections.

Manual SHOOT list entries can also be made for the Sidewinder by visual designation. This is done by padlocking a target with the F2 key on the keyboard, then adding that target to the currently selected missile (Sidewinder) shoot list by pressing the S key on the keyboard.

NOTE: you can add a padlocked target to your wingman's shoot list by pressing M on the keyboard.

When the weapon is in range (parameters) the shoot cue will appear in the HUD and Attack MFD. Pressing the SPACE bar once will launch an externally carried weapon, (NOTE it must first acquire the target as below). If the missile is carried in a dedicated bay one press will put a Sidewinder out of its bay, to 'sniff the air'; when it has acquired its target the growling tone you can hear will have risen to a much higher pitch, and the word "SHOOT" will appear on the HUD. The Attack display will show if the Sidewinder is within range of the target. Pressing the SPACEBAR again will fire the missile.



Short-range kill with the advanced Sidewinder

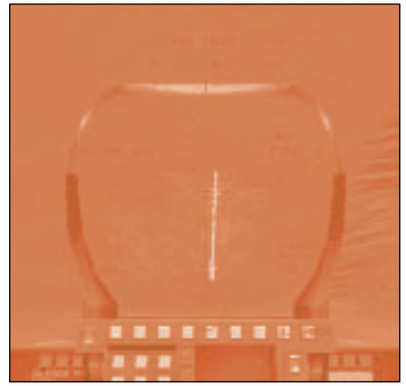
The F-22 gun

The F-22 gun is the M61A2 20 mm rotating 6 barrel Gatling gun, which has an ammunition drum containing 1750 rounds.

To fire the gun you must have the Air-to-Air HUD selected by pressing RETURN on the keyboard, this will also select air-to-air weapons. Keep pressing RETURN until the HUD weapon indicator shows you have selected the gun. Place the gun pipper over the target by maneuvering your F-22.

The word "SHOOT" will appear on the HUD, and Attack displays if you are within gun range of the target. Immediately that the target is in the pipper and the shoot cue is lit, fire your gun by pressing the SPACEBAR, and holding it down so long as you wish to fire.

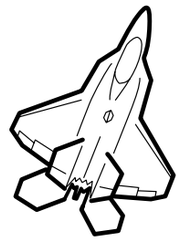
NOTE: that you only have a limited number of cannon rounds, so do not spray bullets all over the place!

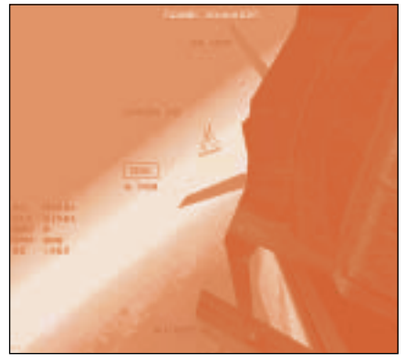


Guns, guns, guns! Get the enemy in your sight and fire

Cannon Snake

When using the Air-to-Air cannon, the path of the shells is shown as a moving 'snake' on the HUD. At the end of the 'snake' is a circle. If the circle is over the targeting box of the enemy aircraft then your bullets have a high probability of hitting.





If you can't win, survive to fight another day

Disengagement

Modern fighters are often short of fuel when it comes to finally doing some fighting. This combined with an inevitable short supply of weapons makes for a quick fight. When the time comes to break off the engagement your main task is firstly to preserve your own life and secondly return a very valuable aircraft home.

For additional information, please refer to the Training section of Total Air War, the Weapons Training DOGFIGHT SIDEWINDER mission. When you have run out of weapons and before your fuel gets too low, you must break off the mission in a clear cut way that avoids the danger of further enemy action.

The F-22 – Air-to-Ground Combat

Air-to-Ground Combat

The F-22 has a secondary air-to-ground role, particularly in the delivery of smart weapons like the JDAM and the growing generation of cruise sub-munitions dispensers, like the European Apache and US JSOW.

Though it is unlikely that the F-22 would ever be employed to deliver 'Iron bombs', it has four wing hard points with a rating of 5,000lb and designed initially to carry one 600 gal. drop tank and two air-to-air missiles each. This means that the F-22 has the capacity to carry a huge amount of ordinance.

It should be remembered that the F-22's predecessor, the F-15 was designed with the immortal words "not a pound for air to ground," and yet the F-15E developed from that air superiority fighter is probably the most capable all weather strike aircraft possessed by any air force in the world today. For the purposes of game play DID has given the player the option of using many weapons that the real F-22 is unlikely to carry.

Bombs and missiles have a realistic blast radius. Bombs damage ground vehicles and planes in close proximity, not just those hit (don't drop a bomb too low now!).

The air to ground weapons fall into five main types:

- Smart self guided missiles
- Sub munitions dispensers
- Smart gliding bombs
- Unguided rockets
- Freefall and Retarded bombs

Smart, Guided, Air-to-Ground Missiles

The AGM-65G Maverick

The AGM65G Maverick, is an IIR guided medium range weapon with a best range of 15 miles. It is mainly used for destroying mobile ground targets, but can also be used against bridges, field HQs and even against small ships and helicopters!

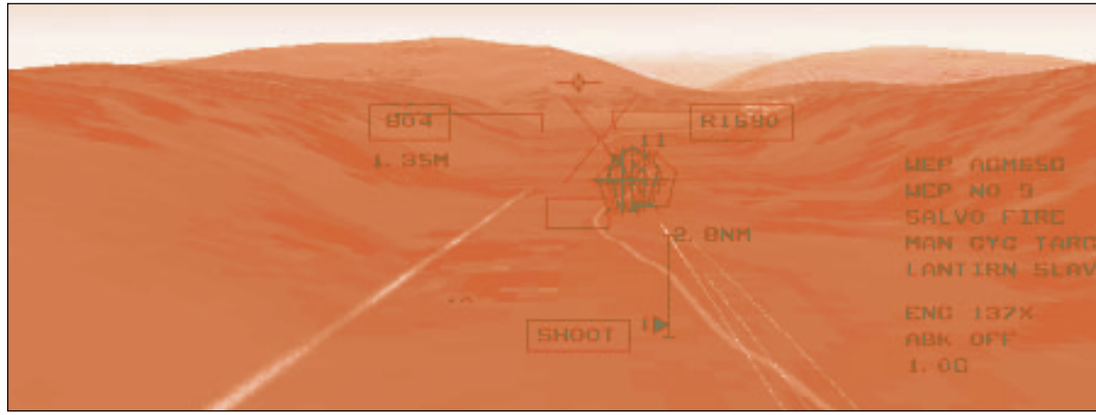
The on board LANTIRN system provides the data for display on the HUD, the Helmet Mounted Display and MFDs. LANTIRN is used further to provide a TV image in the Attack MFD. Once a target has been marked the missile on launch will find its own way there.

To launch a Maverick you must have the Air to Ground HUD selected by pressing the BACKSPACE key on the keyboard. This will also select air to ground weapons. Keep pressing BACKSPACE until the HUD weapon indicator shows you have selected the Maverick. The Maverick is cued to its target by the F-22's IRST primarily, or by data available to the avionics.

The Maverick can have targets designated in the same way as an AMRAAM, i.e. automatic or MFD manual entry in a SHOOT list. Potential targets must be entered into the SHOOT list. One Shoot list is made for each kind of weapon.

Please refer to Shoot lists, in the Avionics section.

The targets will be marked in the HUD, Attack, Situation and Defense MFDs, the first to be fired at is marked in a special way. Please see the Head Up Display and Multi Function Display sections and refer to the



A Maverick on its way to a kill

Target Marking diagrams in each of those sections.

Manual Shoot list entries can also be made for the Maverick by visual designation. This is done by padlocking a target with the F2 key on the keyboard, then adding that target to the currently selected missile (Maverick) shoot list by pressing the S key on the keyboard.

NOTE: you can add a padlocked target to your wingman's Shoot list by pressing M on the keyboard.

Typically a target to be attacked using Maverick will be attacked at maximum range from medium altitude, or more likely the aircraft will approach the area known to contain targets at low altitude and will pop up when in range for 'a good look,' launching weapons in a medium dive, before dropping to the deck and turning away sharply.

When the weapon is in range (parameters) the shoot cue will appear in the HUD and Attack MFD. Pressing the SPACE bar once will normally launch the weapon.

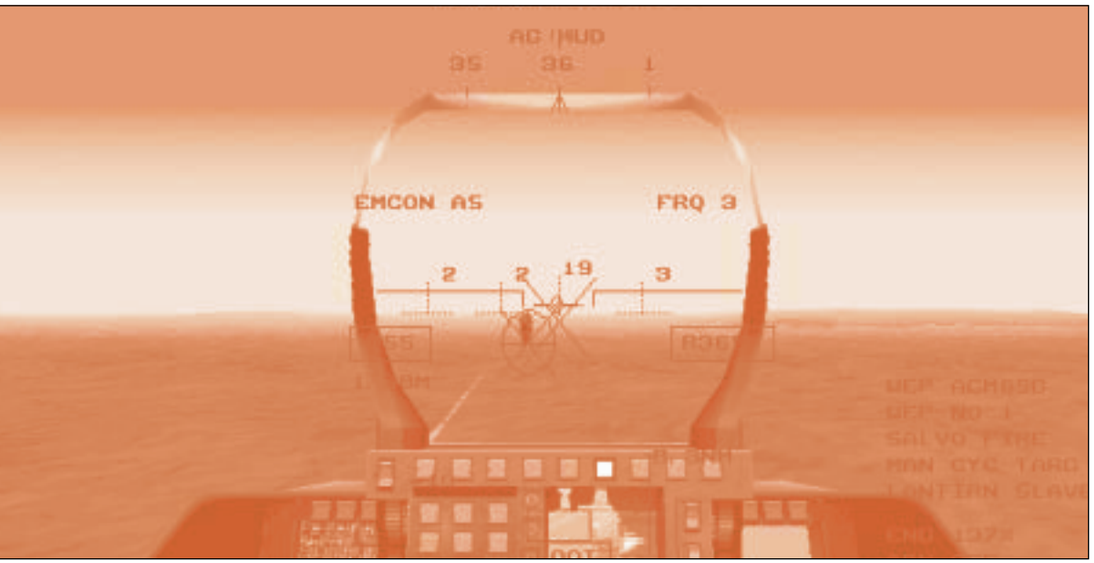
Salvo or ripple drops can be initiated on pressing the SPACE bar if the relevant Salvo, or Ripple buttons have been previously selected on the Systems MFD.

NOTE: that the number of bombs to be released as part of the salvo, or ripple can also be set on the Systems MFD surround.

The image that the Maverick is homing on to is displayed on the Attack MFD by pressing the appropriate button on the Up front MFD surround.

When a number of weapons are in flight you will be able to see the image sent by the oldest launched, (and still in flight), by pressing the appropriate button on the Up front MFD surround.

NOTE: the weapon can also be seen by pressing F8 on the keyboard.



Harpoon attacks against heavily defended ships are always high-risk

The AGM-84A Harpoon

The AGM-84A Harpoon, is an active radar guided long range weapon with a best range of 74 miles. It is a dedicated anti-ship weapon. Once a target has been marked the launched missile will find the ship and attack it at low altitude.

To launch a Harpoon you must have the Air to Ground HUD selected by pressing the BACKSPACE key on the keyboard. This will also select air-to-ground weapons. Keep pressing BACKSPACE until the HUD weapon indicator shows you have selected the Harpoon. The Harpoon is cued to its target by the sensors.

The Harpoon can have targets designated in the same way as an AMRAAM, i.e. automatic or MFD manual entry in a shoot list. Potential targets must be entered into the shoot list. One Shoot list is made for each kind of weapon.

Please refer to Shoot lists, in the Avionics section.

The targets will be marked in the HUD, Attack, Situation and Defense MFDs. The first to be fired at is marked in a special way.

Please see the Head Up Display and Multi Function Display sections and refer to the Target Marking diagrams in each of those sections above.

Typically, the target to be attacked using Harpoon will be attacked at maximum range from low to medium altitude in level flight. When the weapon is in range (parameters) the shoot cue will appear in the HUD and Attack MFD. Pressing the SPACE bar once will launch the externally carried weapon.

The F-22 – Air-to-Ground Combat

The AGM-88 HARM

One of the greatest threats to modern aircraft is the ever increasing number of SAMs. Even a poor nation can purchase significant numbers of lightweight but effective weapons. To counter this the F-22 uses stealth technology and can carry anti-radar missiles.

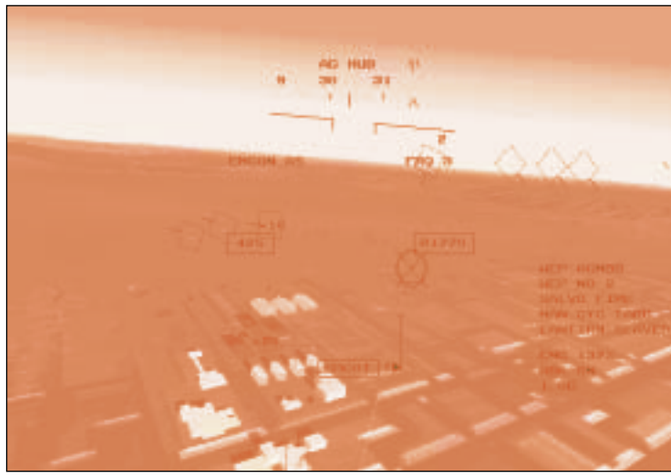
The AGM-88 HARM, homes onto the emissions from an air defense radar and is used principally to knock out SAMs. It has a best range of 15 miles. When a radar starts up and has been detected by the F-22, AWACS, or JSTAR aircraft, it becomes marked. Once launched the weapon homes onto the radar emissions.

To launch a HARM you must have the Air-to- Ground HUD selected by pressing the BACKSPACE key on the keyboard, this will also select air to ground weapons. Keep pressing BACKSPACE until the HUD weapon indicator shows you have selected the HARM. The HARM is cued to its target by the F-22's sensors.

The HARM can have targets designated in the same way as an AMRAAM, i.e. automatically or by MFD manual entry in a Shoot list. Potential targets must be entered into the Shoot list. One Shoot list is made for each kind of weapon. Please refer to Shoot lists, in the Avionics section.

The targets will be marked in the HUD and Defense MFD by a pentagon. The first to be fired at is marked in a special way.

Please see the Head Up Display and Multi Function Display sections and refer to the Target Marking diagrams in each of those sections.



Killing SAMs is an essential part of protecting conventional strike packages

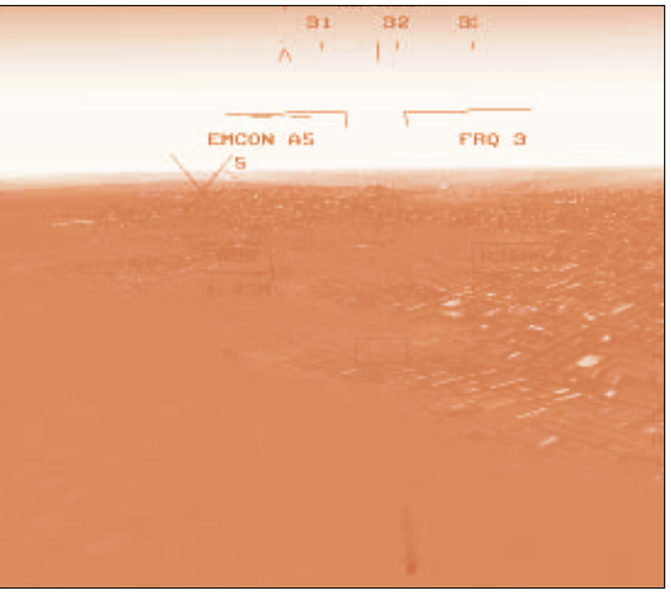
NOTE: any ground target that has a radar signature, (ships, Early Warning radar and SAMs) can be fired at with the HARM.

Manual shoot list entries can also be made for the HARM by visual designation.
This is done by padlocking a target with the F2 key on the keyboard, then adding that target to the currently selected missile (HARM) shoot list by pressing the S key on the keyboard.

NOTE: you can add a padlocked target to your wingman's shoot list by pressing M on the keyboard.

Aircraft flying the SEAD (Suppression of Enemy Air Defense) role normally fly at medium to high altitude and will fly above and behind any aircraft that they are providing cover for. Any target will be attacked as soon as data is available and in range, being launched in level flight, or a shallow dive.

When the weapon is in range (parameters) the shoot cue will appear in the HUD and



JDAM away. Note the marked target within the HUD

Attack MFD. Pressing the SPACE bar once will launch the weapon.

Smart Gliding Bombs

The JDAM

The JDAM, is a Freefall bomb modified by having a special tail cone containing GPS guidance. The bomb has its target pre-programmed at the mission planning stage, so long as the launch aircraft releases the bomb within the parameters indicated on the HUD and Attack MFDs the bomb will hit regardless of weather, daylight, launch altitude, or attitude!

To drop a JDAM you must have the Air-to-Ground HUD selected by pressing the BACKSPACE key on the keyboard, this will also select air to ground weapons. Keep pressing BACKSPACE until the HUD weapon indicator shows you have selected the JDAM.

The JDAM guides itself to the target but must be dropped within a cone that will allow sufficient speed and height for it to reach its target. This is worked out automatically by the avionics. The area that the JDAM can possibly reach at the aircraft's current speed, altitude and attitude is marked by an ellipse on the Attack MFD. So long as the target is within the ellipse, the bomb, when released, will hit the target.

The target is marked on the HUD. When the target is within the bombs parameters, the shoot cue will be displayed on both the HUD and the Attack MFD. Generally when you are using the HUD, you will need to be higher than 500 feet, 1 mile from the target for a low altitude release. Or higher than 10,000 feet 10 miles from the target for a high altitude release before the shoot cue should come on. Because of the great flexibility of the JDAM delivery there is no typical release suggestion. The greater the height and speed, then the greater the stand off range.

When the weapon is in range the shoot cue will appear in the HUD and Attack MFD. Pressing the SPACE bar once will open the main bay doors briefly and release one weapon, if the weapon is carried internally, or will release an externally carried weapon.

However salvo, or ripple drops can be initiated on pressing the SPACE bar if the relevant Salvo, or Ripple buttons have been previously selected on the Systems MFD.

Note: that the number of bombs to be released as part of the salvo, or ripple can also be set on the Systems MFD.

The F-22 – Air-to-Ground Combat

Here, ground targets are designated ready for weapons firing

The GBU-24 Laser Guided Bomb

The GBU-24, is a Freefall bomb which has been modified with extending wings at the tail and a seeker on the nose which looks for laser light reflected off a target. The target is 'marked' by a laser carried by the launch aircraft, or another accompanying aircraft. Like the JDAM it must be launched from within a certain altitude / speed envelope. The LANTIRN TV system is used to find the target, aim and lock the laser.

To drop a GBU-24 you must have the Air-to -Ground HUD selected by pressing the BACKSPACE key on the keyboard. this will also select air-to-ground weapons. Keep pressing BACKSPACE until the HUD weapon indicator shows you have selected the GBU-24.

When you are at least 10 miles off the target, go to the Attack MFD (preferably while the Auto-pilot flies the F-22), by pressing 3 on the extended keyboard. The view through the LANTIRN camera is now selected by pressing the LANTIRN IMAGE button on the MFD surround. The camera will be pointing forwards in the direction of flight, as it is in slave mode normally. To move the LANTIRN camera press CHANGE LANTIRN MODE on the MFD surround. The camera can be moved by pressing the right SHIFT and the CURSOR keys in the desired direction.

Once you have found the general target area, the camera can be zoomed by pressing the TOGGLE ZOOM button on the MFD surround. Adjust the camera so that the cross hairs lie over the desired target, or point on the ground. Press LANTIRN TRACK on the MFD surround and this will track the target point on the ground, putting a lock box over that target point. The laser is now firing at that target and the camera will attempt to maintain lock while the aircraft maneuvers within certain limits.

Unguided rockets - dramatic and effective (see following page)

Once the target has been locked in this way, the shoot cue will be displayed on both the HUD and the Attack MFD, when the bomb, (or bombs) are in firing parameters and can be dropped, at the same time an indicator caret will have progressed up the right edge of the Attack MFD to the uppermost line, this is a good indication of progress and range to release.

NOTE: the LANTIRN RESET button will return the camera to slaved straight ahead mode, as will the CHANGE LANTIRN MODE button.

The GBU series of bombs can be dropped day or night, but bad visibility will hamper both the camera and the laser designator. The bomb is best dropped from medium to high altitudes (10,000 to 40,000 feet) in level flight, or in a shallow dive. When the shoot cue appears in the HUD and Attack MFD, pressing the SPACE bar once will normally drop one externally carried weapon. However salvo, or ripple drops can be initiated on pressing the SPACE bar if the relevant Salvo, or Ripple buttons have been previously selected on the Systems MFD surround.

NOTE: The number of bombs to be released as part of the salvo, or ripple can also be set on the Systems MFD surround.

Unguided Rockets

The LAU-68 rocket

Unguided rockets have been used against ground targets since World War Two. Each rocket packs a big punch and can be fired singly, or as rippled groups, making them much more destructive in a strafe type attack than using the gun.

To fire the LAU-68 rocket you must have the Air-to-Ground HUD selected by pressing the BACKSPACE key on the keyboard. This will also select air to ground weapons. Keep pressing BACKSPACE until the HUD weapon indicator shows you have selected the LAU-68. Place the rocket pipper over the target by maneuvering your F-22.

When you are aiming at a fast moving ground target, provide a little lead to your target by aiming slightly ahead of it. The unguided rocket attack is best made in a shallow to steep dive from 10,000 feet or lower.

The word “SHOOT” will appear on the HUD and Attack displays if you are within rocket range of the target. Immediately that the target is in the pipper and the shoot cue is lit, fire your rockets by pressing the SPACEBAR or trigger, once for single rounds, or more if the relevant Salvo, or Ripple buttons have been previously selected on the Systems MFD surround.

Freefall, Retarded and Cluster bombs

There are three main techniques to be used to deliver a Freefall bomb:

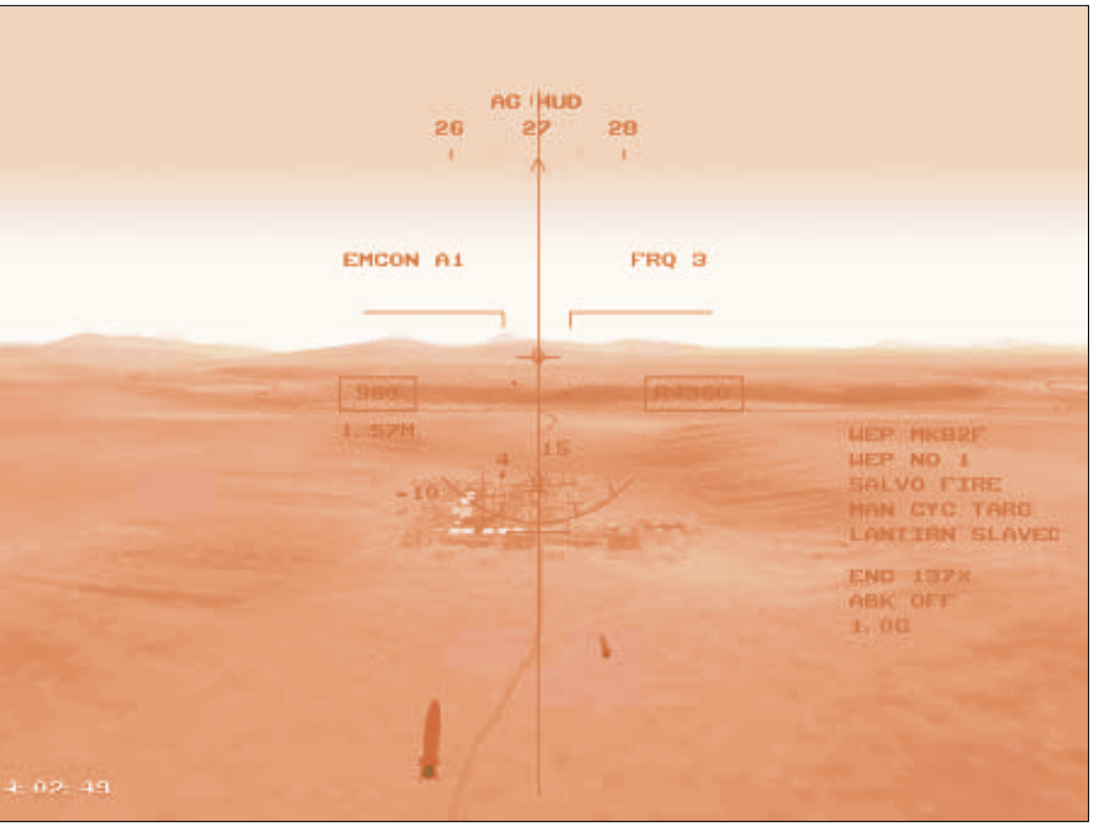
- From a shallow dive, usually below 20,000 feet and above 2,000 feet.
- Toss bomb (where the aircraft pulls up and releases the bomb, imparting a ballistic trajectory and greater range to the bomb), the maneuver is usually carried out up to altitudes of 20,000 feet.
- Level flight and release, from any altitude down to 1,000 feet.

The Freefall (iron) bomb is similar in design to the millions that were dropped during the Second World War.

Retarded bombs are designed to be dropped in very low level attacks where the extra drag created by their retarding mechanism literally pulls them clear of the bombing aircraft, saving it from blast effects.

The Cluster bomb is delivered in a shallow dive, or from level flight at altitudes below 10,000 and above 1,000 feet. Shortly after release the bomb breaks into multiple bomblets which scatter over a wide area.

All three types of bombs, regardless of delivery method, are targeted in the same way. **To drop a Freefall, Retarded, or Cluster bomb** you must have the Air-to-Ground HUD selected by pressing the BACKSPACE key on the keyboard, this will also select air to ground weapons. Keep pressing BACKSPACE until the HUD weapon indicator shows you have selected the MK82F / MK82R, MK83F, or the MK20 respectively.
A bomb fall line will be displayed on the HUD and a mission planned target will be marked



When the CCIP crosses the target, release the bomb

by a cross. The CCIP (Continuously Computed Impact Point) marked by a small caret will progress up the bomb fall line as you near the target. Immediately that the caret lies over the target the bombs must be immediately released by pressing the SPACE bar. Once will normally release a single externally carried weapon at a time. However salvo or ripple drops can be initiated on pressing the SPACE bar if the relevant Salvo, or Ripple buttons have been previously selected on the Systems MFD surround.

Air-to-Air Combat Tactics

In the Training section of Total Air War are a series of missions which should be viewed initially as training missions. The Missions are written so that each contains more than the aircraft and targets necessary to learn the specific lesson.

Using EMCON

Either the pilot (in manual EMCON), or the F-22 avionics (in auto EMCON) can decide which of 5 EMCON states to be in.

EMCON1 is the stealthiest and EMCON5 is the least stealthy, allowing the most use of radar and radio. The EMCON system is there to decide how stealthy the F-22 should be, In its auto mode the F-22 would normally travel in EMCON1. When a potential enemy is spotted by the aircraft systems it will gradually increase the EMCON condition as the opponent gets closer in non regular steps, based on the range of the F-22 and the potential enemy's detection systems and weapons.

Please refer to EMCON in the preceding Avionics section.

Using the IRST

The IRST is a highly sensitive Infrared camera that has the ability to zoom onto a distant target magnifying the image for display on the Up front MFD. This allows the pilot to visually identify targets at well beyond visual (eyeball) range.

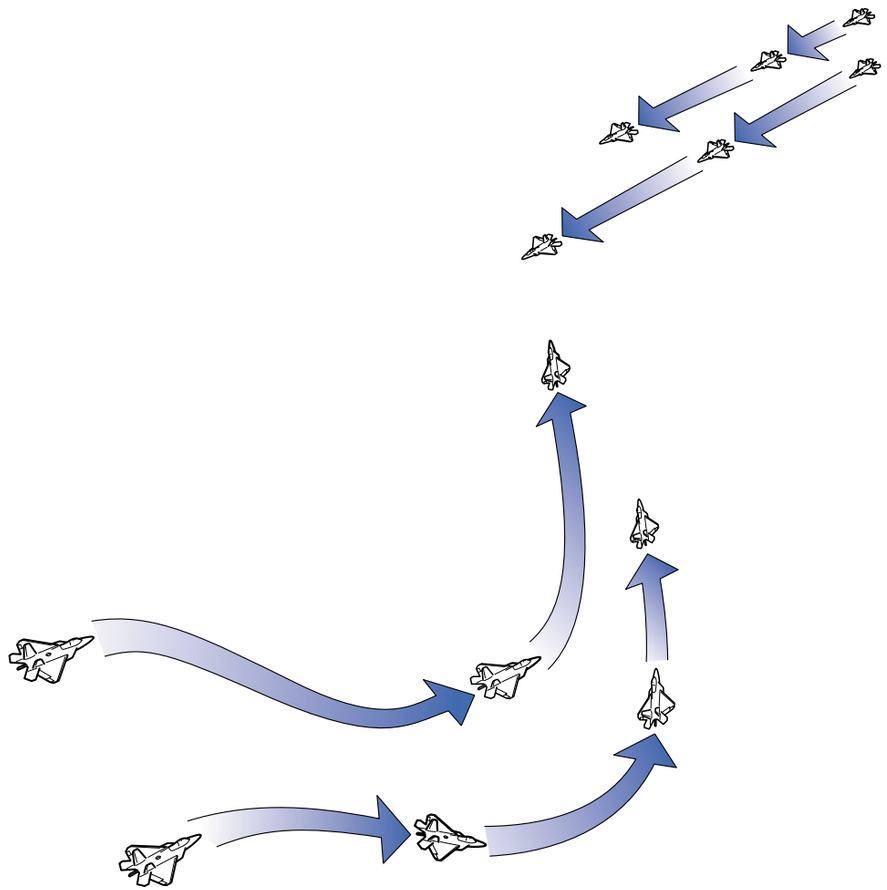
In EMCON 1 the IRST becomes the primary on board search and track device and can also be cued to a potential target by avionics received emissions. As such it is a very stealthy means of acquiring targets.

Target information gained by the IRST is pooled with all other sensor information allowing all air to air and air to ground guided weapons to be cued to their targets.

Please refer to IRST in Avionics.

Eyeball and Shooter

The eyeball shooter method of attack is used when a visual confirmation of a hostile aircraft is needed, which may occur when the nations involved are not at war but may be involved in a military stand off, or show of force. Typically your fighters would be involved in a head on approach to intruding aircraft. They will have been alerted to the presence of these aircraft by one sensor source or another and will attempt to offset their flight paths by several miles allowing them to close the unknown contacts from a front quarter. Your two fighters will be separated by over a mile, the lead will be able to visually ID the bogeys as bandits, while the number two is ready to fire immediately on command at the trailing contacts. Only the lead fighter will come within the unidentified contacts visual range and will turn to engage the enemy lead immediately if he has given the command for his wingman to launch. This tactic will hopefully quickly turn a 2 on 4 attack into a 2 on 1.



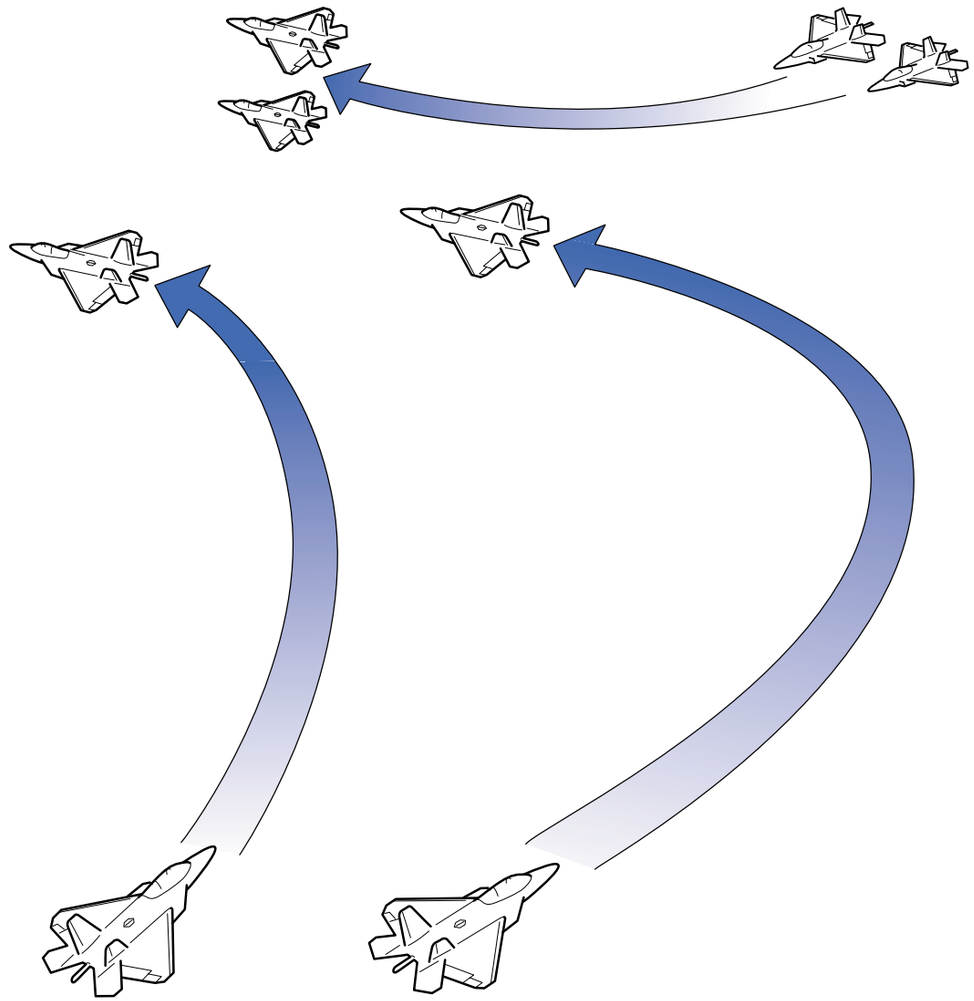
The number two gets ready to fire while the lead 'eyeballs' the targets

The F-22 – Maneuvers

Drag Left

Dragging left or right is a tactic where one fighter of a pair becomes the bait for enemy aircraft and flies to the left or right. Once the opposing aircraft have followed the bait, the other fighter of the pair swings in behind them and launches an attack.

In some BVR situations the lure can first go one way and then be switched to the other direction. The tactic has been described best as: "Hold them by the nose and then kick them in the pants!"

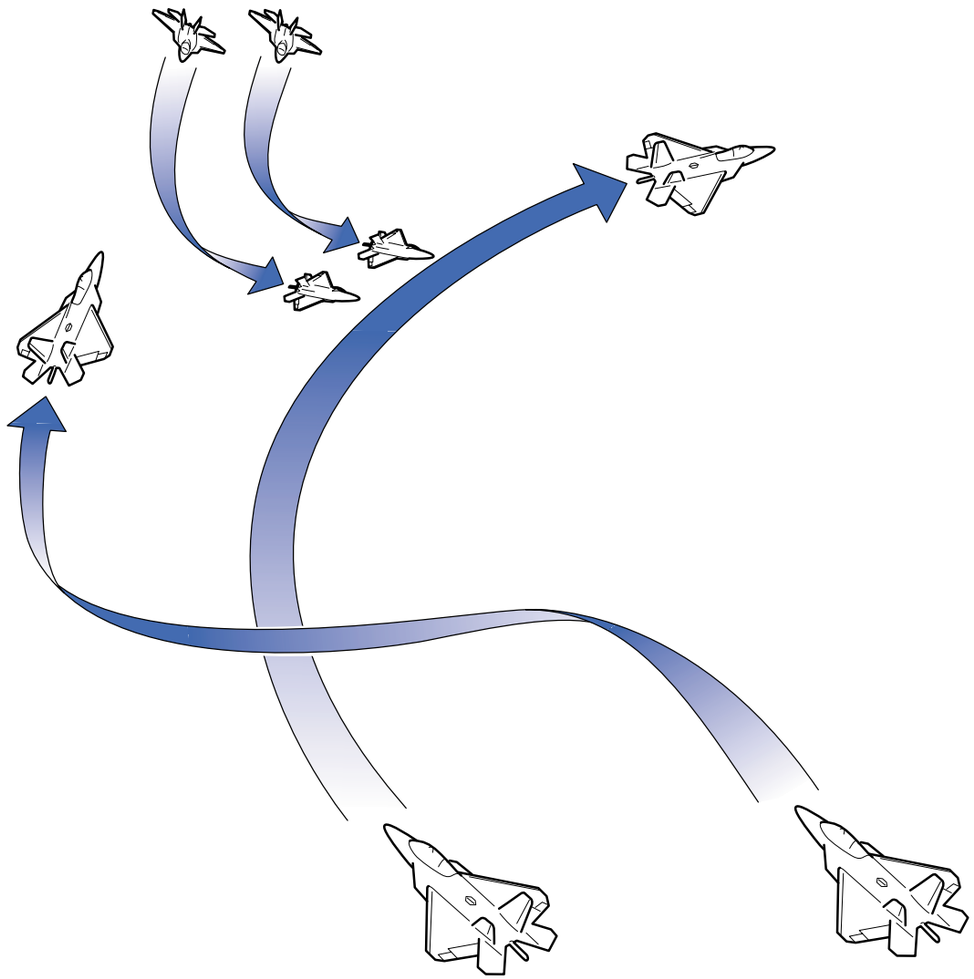


"Hold them by the nose and then kick them in the pants!"

Offensive Split

A pair of fighters can carry out this tactic while in a combat spread. One fighter draws the attention of the enemy while the other (hopefully unobserved) sneaks around the back.

It could be a follow on to the Eyeball and Shooter method: when the lead gains visual contact and gives the order for his wingman to fire, the lead is observed by the enemy who will certainly turn towards him. The wingman who is the shooter goes low and undetected turns hard in a climbing turn behind the enemy.

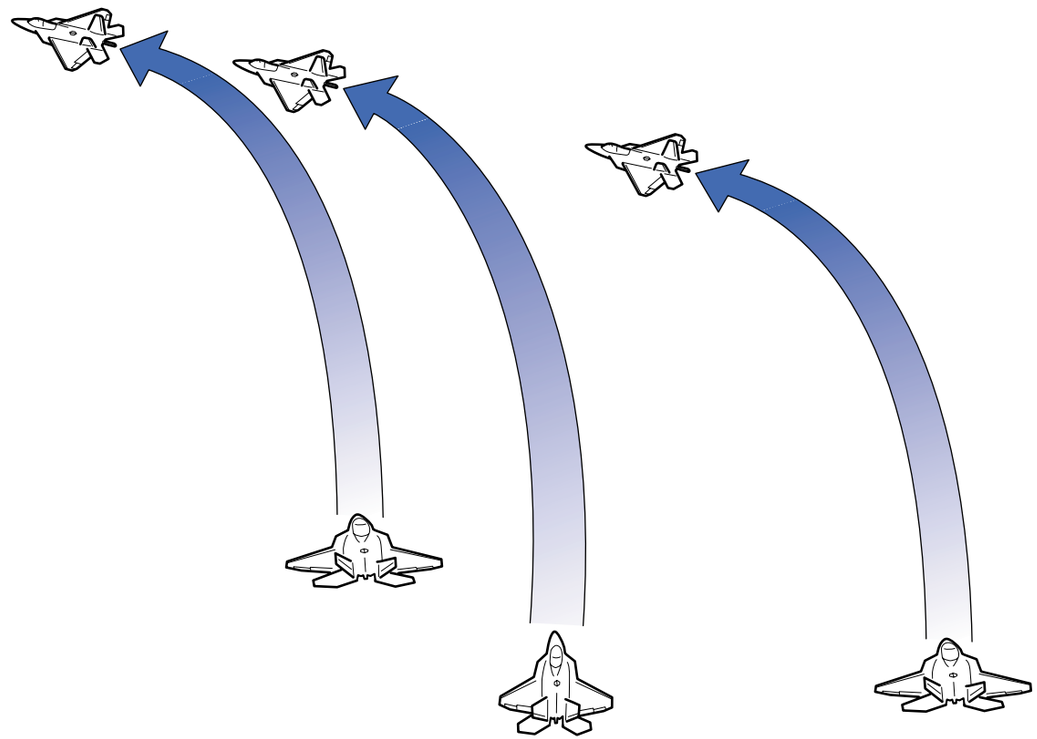


Before he knows it, the enemy is in a tight spot

The F-22 – Maneuvers

Sandwich Left (Bracket Left)

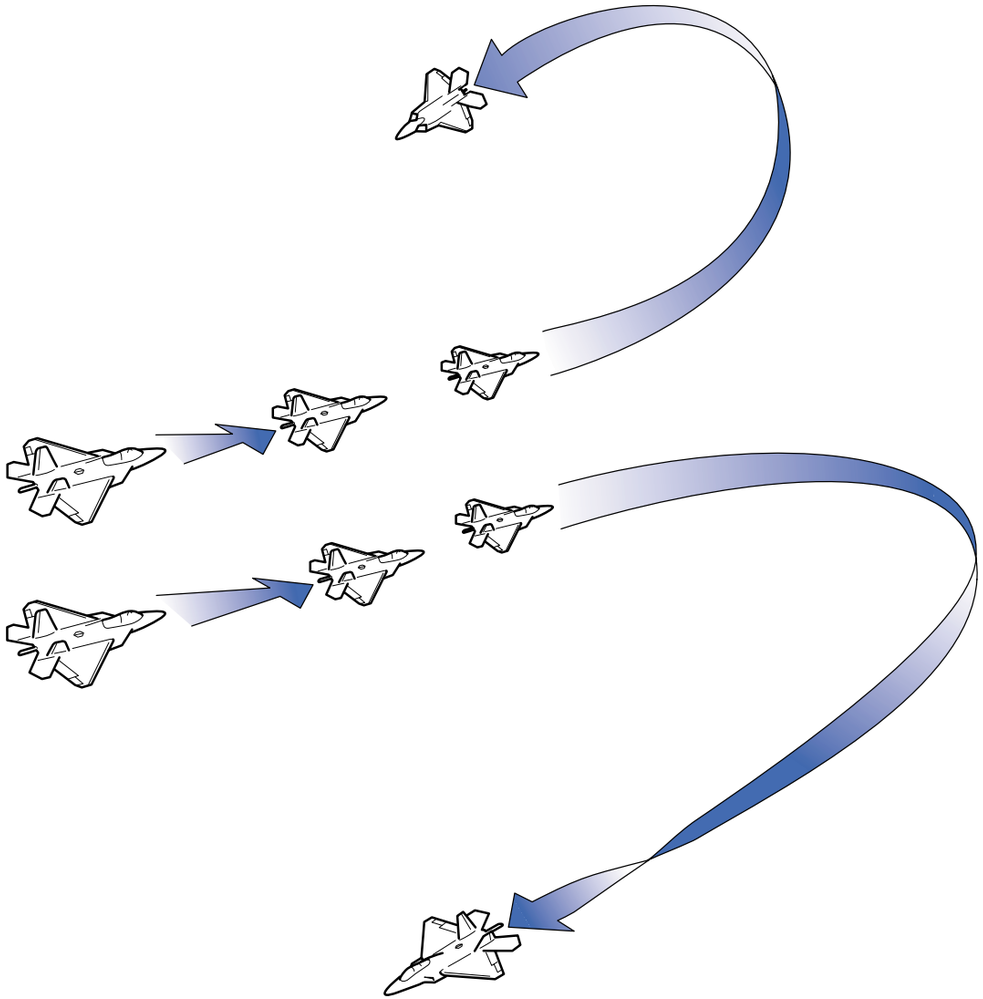
Still the oldest trick in the book for a pair of fighters. When one aircraft is attacked from his rear quarter he turns to the opposite side to which his wingman is on, thereby drawing the attacker further while his wingman swings neatly in behind ready to dispatch the attacker with a heat seeking Sidewinder once the first fighter breaks out of the danger area.



Sandwich of death

Defensive Split

This a maneuver to either foil or deal effectively with an attack from behind by an equal number of fighters. One of the attacked pair will go high and attempt to loop behind the attackers, drawing their attention as a potential victim as he will lose energy faster than his wingman who has gone low by rolling over and pulling a rapid dive. The wingman loops up to deal with the attackers rejoining the fight that the first fighter is now drawing down to meet his wingman.

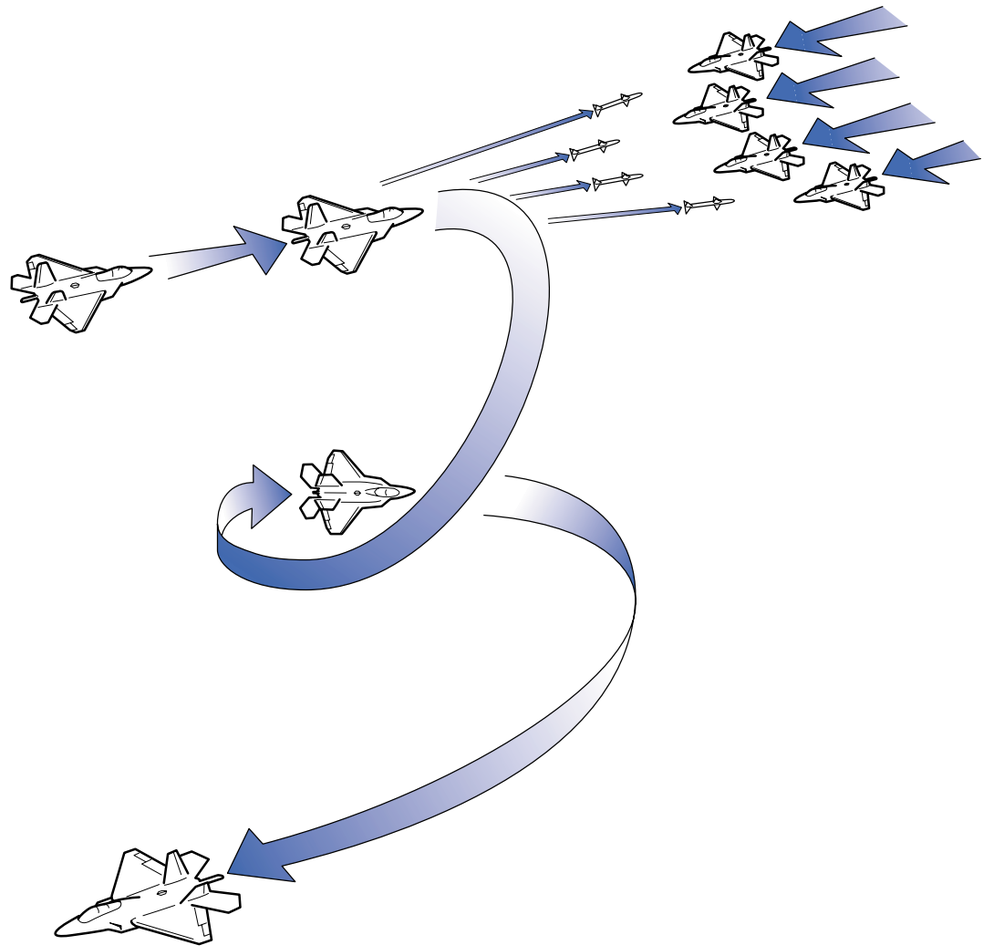


One goes high, the other goes low. Luck and skill leads to survival

The F-22 – Maneuvers

The Grinder

The United States Air Force uses a tactic called the `Grinder', a technique that involves a flight of fighters maneuvering to launch a salvo of long range missiles against an opposing force and then rapidly spiraling to a lower altitude and either escaping, or regrouping. This technique maximizes their chance of success and reduces the risk of losses. The maneuver can be repeated over until all the opposing force is destroyed. Please refer to BVR combat in the Air to Air Combat section.



A barrage of missiles will make any enemy think twice

Stealth Attack
Stealth is a huge asset to have if your mission involves a sneak attack. It can be especially useful if your government wishes to take out certain undesirables while maintaining a plausible denial!

ECM, Chaff and Flares
ECM, Chaff and Flares all have the job of preventing or confusing an attack on you by missiles, but achieve this objective in different ways.

Electronic Counter Measures take many forms but basically prevent enemy radar from seeing a clear picture of the jamming aircraft.

Chaff is a last ditch attempt to thwart a missile attack by dumping large amounts of aluminum strips which temporarily blinds the radar of a missile, fighter, or ground station.

Flares are also a last ditch attempt to foil a missile attack, but being a high intensity heat source are aimed at heat seeking missiles and blinding IRST sensors.

Wingmen Commands

Press TAB on the keyboard, this will present a menu on the top left of your Helmet Mounted Display. Selecting one of these (with the exceptions of options 1 and 9, which are context sensitive), will lead into a further set of options.

Formations
Under option 2, FORMATION, is a list of formations to apply to your flight. Some of these formations can be close (wingtip to wingtip), while others are combat spread formations with a large horizontal separation between individual aircraft.

Card
Card is the most useful formation for a four aircraft flight, providing mutual cross cover. The four aircraft are horizontally spaced at the four corners of a playing card shape.

Deuce
Deuce is specifically a formation for two aircraft on a SEAD mission. The first aircraft is usually the bait, while the second flying above and behind watches for any radar that tries to track the first and launches a HARM at the radar source.

Sweep
Sweep is a line abreast formation used for fighter sweeps and by all aircraft to cross an obstacle such as a coastline. All aircraft in the formation will cross at the same time dividing potential ground fire between them and thereby reducing the risk to individual aircraft.

Strike
Strike is a line astern formation used to launch, or drop weapons on a ground target. Separation must be adequate to prevent aircraft flying into the explosions created by the aircraft ahead.

Fingertips
Fingertips can apply to two or four aircraft. The aircraft form one half of an arrow, forming up on the leader.

Vic
Vic is the V formation loved by airshow spectators the world over and included here for fun!

For additional information, please refer to the Training section of Total Air War. Look at the Key Card and In Game Speech below.

In Game Speech

The F-22 has 4 preset radio frequencies for communication with other aircraft and the ground. You can communicate with your Wingmen on all 4 frequencies, each frequency also enables you to talk to one other group as outlined below:

NOTE: whenever you can talk to a group on a specific radio frequency you will be able to hear what that group is saying to you. Quick access to wingmen commands can be gained by pressing TAB on the keyboard.

Please see Wingmen Commands above. For additional information, please refer to the Training section of Total Air War. Look at the Key Card, In Flight Communications. In addition please go to the Avionics section for reference to 'Bitchin Betty'.

A full list of all player selectable phrases appears below.

Radio Frequencies

Frequency PUSH 1
Frequency PUSH 1 is for talking to the airfield tower and local airfield air traffic control. To select press 1 on the keyboard, or the relevant button on the up front MFD panel.

Frequency PUSH 2
Frequency PUSH 2 is an open channel for aircraft allowing you to broadcast messages, warnings and orders and also enables you to talk specifically to the AWACS. as this channel is open you will be able to hear radio traffic between other aircraft. To select press 2 on the keyboard, or the relevant button on the up front MFD panel.

Frequency PUSH 3
Frequency PUSH VICTOR 3 is also for talking to the AWACS but is a closed channel for talk between you and the AWACS handling your flight. To select press 3 on the keyboard, or the relevant button on the up front MFD panel.

Frequency PUSH 4
Frequency PUSH VICTOR 4 allows you to talk to an air refueling aircraft. To select press 4 on the keyboard, or the relevant button on the up front MFD panel.

NOTE: When starting a new mission the radio frequency will be set to PUSH 1.

Talking to other groups
Care has been taken to present the 'enthusiastic user' with speech relevant to each situation, this will be particularly apparent when seeking instructions to take-off, or refuel. For the less experienced user, do not let the depth of speech get to you! Try pausing the game while you make a selection.

continued on page 142

The F-22 – Communications

F-22 Speech

FRQ 1
- **1** Wingmen
- **2** Airfield

FRQ 2
- **1** Wingmen
- **2** AWACS
- **3** Broadcast
- **4** Help

FRQ 3
- **1** Wingmen
- **2** AWACS

FRQ 4
- **1** Wingmen
- **2** Refueler

Wingmen
- **1** Engage
- **2** Formation
- **3** Combat
- **4** Maneuver
- **5** Abort Mission
- **6** Radio
- **7** Disengage

1 Say My Take-off Time
2 Vector For Recovery
3 Direct Approach
4 Teardrop Approach
5 Circuit Approach
6 Finals

1 Leave the Area
2 Leave, or be Shot Down

1 Bandits Hot
2 Threat Hot

1 Request Divert Airbase
2 Where is the Tanker
3 Clearence to Base

1 Where is the Tanker
2 Refuel Permission

1 Card
2 Deuce
3 Sweep
4 Strike
5 Fingertips
6 Vic

1 Engage My Target
2 Engage Bandit
3 Engage Hostile
4 Engage Threat
5 Drag Left
6 Drag Right
7 Bracket Left
8 Bracket Right
9 Complete

1 Break Left
2 Break Right
3 Break High
4 Break Low

1 Change to Radio Frequency 1
2 Change to Radio Frequency 2
3 Change to Radio Frequency 3
4 Change to Radio Frequency 4
5 Say Again

As real as it gets. Accurate speech simulation, easily accessed via a menu

continued from page 139

When you wish to talk to your Wingmen **Remember** that this can be done in any radio frequency by picking option 1 Wingmen and choosing the relevant option. Or press TAB on the keyboard, this will present a menu on the top left of your Helmet Mounted Display Selecting one of these (with the exceptions of options 1 and 7). Once key phrases are learned you will be able to short cut them as in this example, to give the order *"ENGAGE MY TARGET"*, press TAB, 3, 1.

When you wish to talk to the airfield both before, or during flight ,first select radio frequency PUSH 1, pick option 2 Airfield and choose what you wish to say from the options presented on the top left of your Helmet Mounted Display.

Remember that any replies from the airfield can only be heard on this frequency!

When you wish to talk to the AWACS, first select radio frequency PUSH VICTOR 3, (or PUSH 2), pick option 2 AWACS and choose what you wish to say from the options presented on the top left of your Helmet Mounted Display.

Remember that any replies from the AWACS can only be heard on this frequency!

When you wish to talk to the refueler, first select radio frequency PUSH VICTOR 4, pick option 2 Refueler and choose what you wish to say from the options presented on the top left of your Helmet Mounted Display.

ACMI (Air Combat Maneuvers Instrumentation)

Introduction

ACMI is a highly cost effective tool for training pilots. It features an under-wing data pod which relays the aircraft's position in 3D space to a ground station, and calculates the path of virtual weapons once a lock has been obtained and the trigger pulled. Instructors on the ground assess which students have scored kills, and call the defeated pilots out of the fight. Later, in the debriefing room, a 3D reconstruction of combat is replayed from the collected data using simple, graphical representations of aircraft, weapons and the landscape. Mistakes are easily pointed out, and the lessons learned.

In TAW, ACMI is one of the best tools for learning the skills of modern air combat. For customers of DID products, ACMI has always been one of the most requested features, which is why TAW has probably the best system of its kind. Now the player is able to record, analyze and compare performance in combat.

Like the real ACMI, data is collected from the player's aircraft, allowing a graphical portrayal to be replayed afterwards.

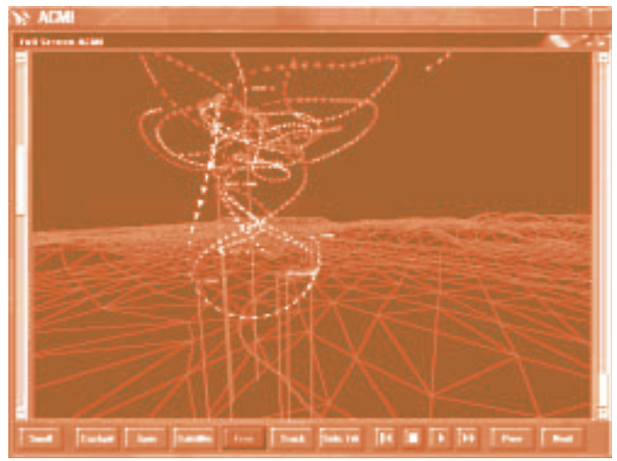
In some cases the ACMI data from a previous flight is the ideal way to brief new pilots.

ACMI Modes

The ACMI system can run in one of four modes, each mode has a different screen layout:

In-Cockpit Recorder Mode

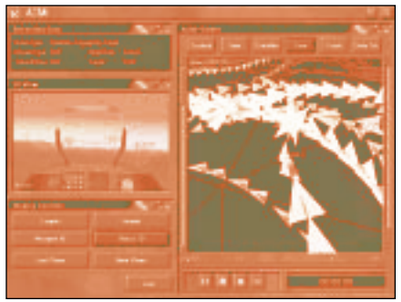
SHIFT R starts a recording, and red on-screen text warns you that a recording is being made. Pressing SHIFT R again stops the recording. When the mission is over, go to the ACMI Debrief Screen to view the ACMI recording and save it for future use. The system has been designed so that each minute of ACMI data takes only a few kilobytes of space on your hard disk, making ACMI files ideal for sending over the Internet.



ACMI in Action

ACMI

In-Cockpit ACMI Mode
The ACMI module is started from the cockpit while you are flying a mission by pressing SHIFT A. The full ACMI interface will be dis-



played, showing what is going on around you in real time. An indicator will show whether or not you are recording at that time. See 'ACMI Interface' for a complete description.

Debrief Player Mode
This screen is accessed at the end of a mission to view the recording you have made during the mission, and to save that mission data if required.

Playback Mode
This is started from the TAW Main Menu, and is used to load and view previously recorded missions. These can be your recordings, or ones copied from other pilots.

ACMI Interface

The ACMI module screen contains the main view screen, the view controls, and the video controls. The ACMI consists of the following panels:

Recording Data
This displays information and game data about the current recording. These are: Game Type, Mission Type, Flight Role, and Take-off Base. This information is stored when the player starts the recording.

3D View/Recording Log
If the ACMI is started while flying a mission, this panel will display a scaled-down 3D game view.

All key presses, and joystick movements will work within this view, which means that you continue flying your mission while in the ACMI.

If the ACMI is in a playback mode, this area will contain a scrolling message log. The log shows colour coded text details about what happened in the recording, such as plane hits and deaths. User recorded messages are also displayed here.

ACMI Display Controls

This area contains the following buttons:

Targets
Shows who is targeting whom by drawing a moving dotted line between an aircraft and its target. The line colour is that of the targeting plane, and the line moves towards its target.

Height
Draws a gray line from each plane down to the ground, which gives a better indication of how high each plane is flying.

Weapon ID
Identifies weapons by overlaying a text description at the head of the weapon trails.

Object ID
Identifies objects by overlaying a text description at the head of each object trail.

Next Plane
Moves the view focus to the next plane in the recording.

Last Plane
Moves the view focus to the previous plane in the recording.

ACMI View Controls

The viewer contains the main viewer screen, the viewer controls, and the video controls. The selectable views are:

Cockpit
Puts you in the cockpit of the currently focused aircraft, which means you have a pilot's eye view of the recording.

Spin
Continuously spins around the currently focused aircraft.

Satellite
A top down view of the currently focused aircraft.

Free
A user moveable camera. Hold down the left mouse button in the view area, and then drag the mouse around to move the camera around the currently focused aircraft.

Track
Places the camera so that it points towards the currently focused aircraft's target.

Side Track
Places the camera at 90 degrees to the current aircraft and its target.

The Main Viewing Window

The main viewing window contains two scroll bars, these are:

Zoom scroll bar
Located on the left of the main view, this zooms the view distance of the current view. This has no effect in the cockpit view.

Aircraft trail length scroll bar
Located on the right of the main view, this scroll bar changes the trail lengths of the objects in the view.

Changing the trail lengths can avoid clutter or help to increase the frame rate if there are a lot of objects in view.

ACMI

Full Screen Mode

ACMI Smaller Window

ACMI Video Controls

Below the main view area are the video controls. From left to right these are:

Rewind to Start
Takes you back to the start of the currently loaded recording.

Stop
Stops, or pauses the recording or playback of ACMI.

Play / Record
In playback mode there is a playback button, e.g. for use during debrief. In record mode there is a record button, e.g. for use during a mission.

Fast Forward
Speeds the recording forward at four times normal speed.

Timer
Next to the video controls is a timer, which shows the current play or record time in seconds.

'FULL' button
When the ACMI is in one of the playback modes, a 'FULL' button will appear that lets you expand the view area to full screen mode.

'SMALL' button
Pressing the 'SMALL' button after using the 'FULL' button will take you back to a smaller window.

Using ACMI

One of the biggest problems of air combat is getting an understanding of the complex spatial relationships that occur in a dogfight. ACMI offers a whole new way to view the action, and obtain a better understanding of how different maneuvers and weapons should be employed.

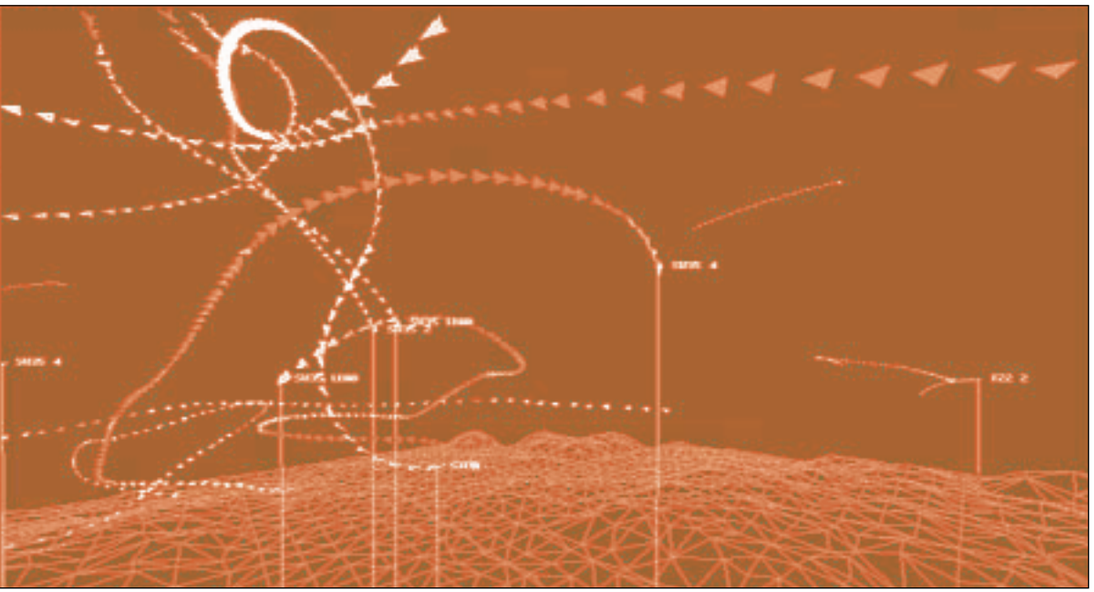
It is possible to initiate an ACMI recording during flight and view it afterwards. Or it is possible to enter the ACMI interface while you are flying, for real-time analysis of actual flight through an abstraction in simple graphics.

During a mission you can start and stop a recording by pressing SHIFT R. This will toggle the recording on and off. If the ACMI is recording you will see a red 'REC' symbol on the bottom right corner of your screen.

Alternatively, during a mission, it is possible to start the ACMI screen by pressing SHIFT A on the keyboard. In this case you will be able to watch what is happening in real time.

Pressing SHIFT A again, or clicking on Exit within the ACMI window, will take you out of ACMI again.

When an aircraft is hit, you will see a small star shaped graphic that represents an explosion. Weapons tracks are shown as dotted lines, and aircraft or weapons identification is made easy by labels on screen. A colored line will also reveal who is tracking



during a multiplay mission, any messages sent by you will be recorded in the 3D View / Recording Log. A typed message can be sent to everyone by pressing 5 on the keyboard, and then typing your message, ending it with one press of the RETURN key. Similarly a typed message can be sent to your team members by pressing 6 on the keyboard, type your message, and then press the RETURN key.

You can index an event of importance by sending a message to everyone as above, type an index message while making a recording in flight. For example “sensor contact made” will give you a suitable event index within a recording of BVR combat.

Player Views

Introduction

In TAW there is a very wide choice of player views. Each view has its own merits, and choice depends very much on the player's preference. For example, looped fly-by is an excellent way to enjoy aerobatic maneuvers from an external view -especially when using thrust vectoring. Padlock view adds a realistic head movement to the cockpit view, enhancing the feeling of flight. Some players, on the other hand, prefer the straightforward HUD only view, with its uncluttered display.

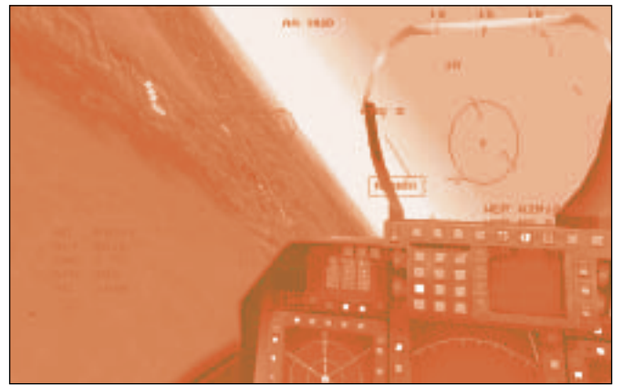
See the supplied Key Card for keyboard combinations necessary to operate the different views.

Using the Views

Finding your favorite combination of views takes practice and experimentation. Once you have found the best combination, programming the views onto a programmable joystick will make life easier.

Padlock Views

In TAW there are a number of padlock views. A padlock view is an internal tracking view that simulates the pilot looking around the cockpit towards a given object. For example, the F2 view is a current target padlock, which means that the pilot's head will turn to keep that object in view. The padlock views cannot be used to padlock planes outside visual range.



Realistic head movement while tracking targets in the wide-angle padlock view

Padlock views are more realistic than external views, and more flexible than the normal forward-looking view. However they may be confusing to start with; practice helps a lot. Padlock views are on F2, F3, and F4, these work as follows:

F2 - Current weapon target padlock.
This view will padlock to the currently locked target. This is obviously useful for lining up missile shots etc. When the HUD is in ILS mode the F2 key will padlock to the runway you have been instructed to land on. Pushing F2 again will show an external view of your plane with the runway behind. You will be unable to use this view if you are out of range of the landing strip or if no runway has been allocated to you.

F3 - Current threat padlock.
This view will padlock to any missile that has been fired at you. If there are no missiles, the view will padlock to the closest plane that is targeting you.

Player Views

F4 - View padlock
This gives you the flexibility to padlock to any object within the local area, e.g. planes, ground vehicles and buildings. It is independent of weapons, and is equivalent to scanning with your eyes. However, if you 'View Padlock' onto a potential target, press 'S' to put a weapons lock on that target.

There are a number of keys that control the View Padlock.

F11 - View Padlock filter
Cycles around Air, Ground and Static objects: Air being aircraft, Ground being ground vehicles, and Static meaning buildings and structures.

To **change the current View Padlock** object you use the following keys:

Z
View next object in flight or group.

****
View previous object in flight or group.

Shift Z
Skip view to next flight or group.

**Shift **
Skip view to previous flight or group.

The keys above will work for static objects, but you will need to be much closer to see them.

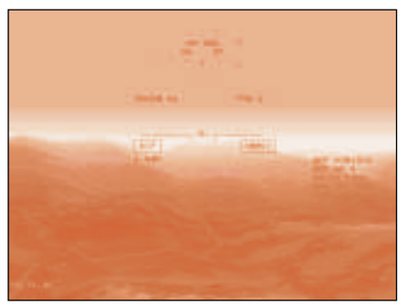
When you have a View Padlock you can use F4, Shift F4, F9, Shift F9, F10 and Shift F10 to view that object in different ways (See the Views Keys section below). If you have a View Padlock on an object there are two other useful functions you can perform. The first is to add that object to your shoot list by pressing S on the keyboard. The second is to add the current padlock object to your wingman's shoot list by pressing M on the keyboard, this is very useful if you are out of weapons and still want to designate targets.

NOTE: The View Padlock filter and object are automatically set to the 'objects' view using F2.

Views Keys

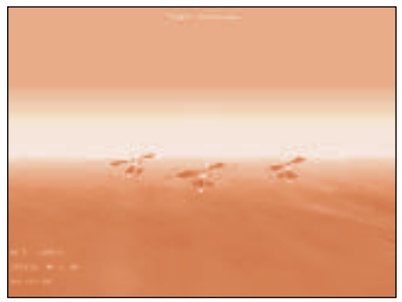
The 'F' keys from F1, to F11 provide a range of views around the F-22, and other mobiles in the world; many of these keys will padlock a mobile, cycle between related views and can be modified by pressing SHIFT on your keyboard.

F1
Toggle virtual cockpit on / off.



SHIFT F1
Check your six.

F2
Current weapon target padlock. Toggles between internal view, and external view.

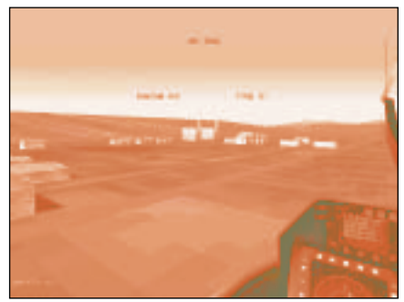


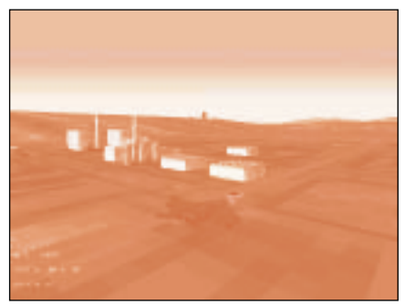
SHIFT F2
External target to player.

F3
Toggle threat padlock between internal view, and external view.

SHIFT F3
External view threat to player.

F4
Toggle View Padlock between internal view, and external view.





Player Views

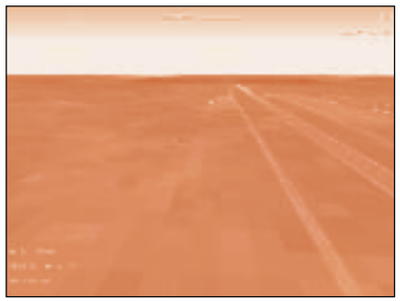
SHIFT F4
External View Padlock object to player.

F5
Toggle, padlock to wingman, external view, player to wingman.

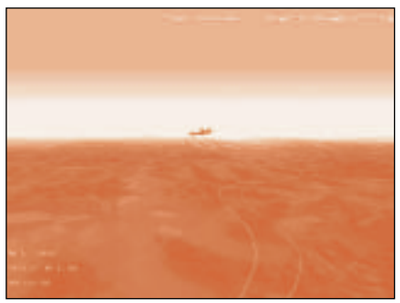
SHIFT F5
External view , Wingman to Player.

F6
Player fly-by.

SHIFT F6
Looped player fly-by.



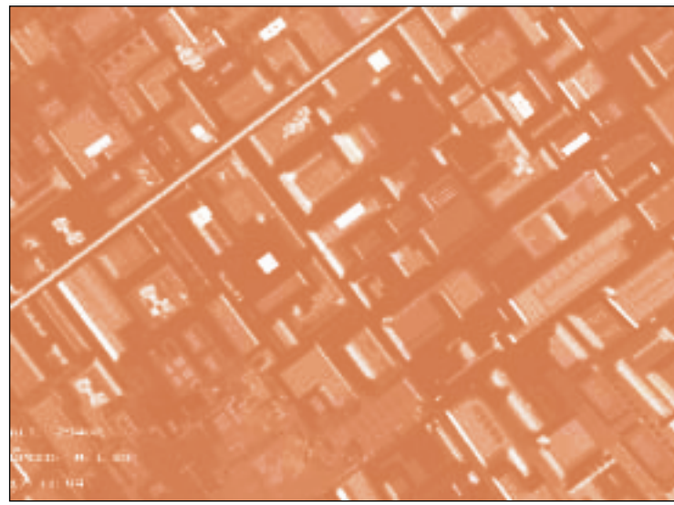
F7
Player moveable external view, (you can use SHIFT and CURSOR keys to alter your viewing position).



F8
Cycle missile view / pylon view.

F9
View Padlock selected moveable external view.

SHIFT F9
View Padlock selected fixed external view.



F10
View Padlock selected flyby.

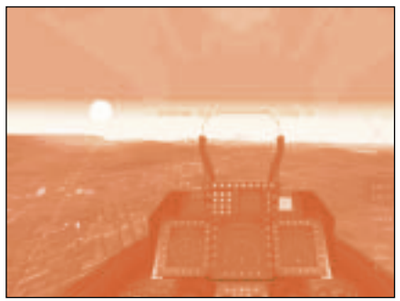
SHIFT F10
View Padlock selected looped flyby.

F11
View Padlock browse filters Air, Ground Mobile target, or Ground Static targets.

The Wide Angle Camera

The internal views selected on the F1, F2, F3, and F4 keys can be individually modified from normal narrow angle cameras to wide angle cameras by pressing K on the keyboard while in each view.

Normal View



Wide Angle View

Extended Keyboard Cockpit Views

The extended keyboard numbers each provide a particular view of your MFDs.

NUM 0 View Systems MFD.

NUM 1 View Defense MFD.

NUM 2 View Situation MFD.

NUM 3 View Attack MFD.

NUM 4 View combined Communications and warnings MFD.

NUM 5 View Up Front MFD and Panel.

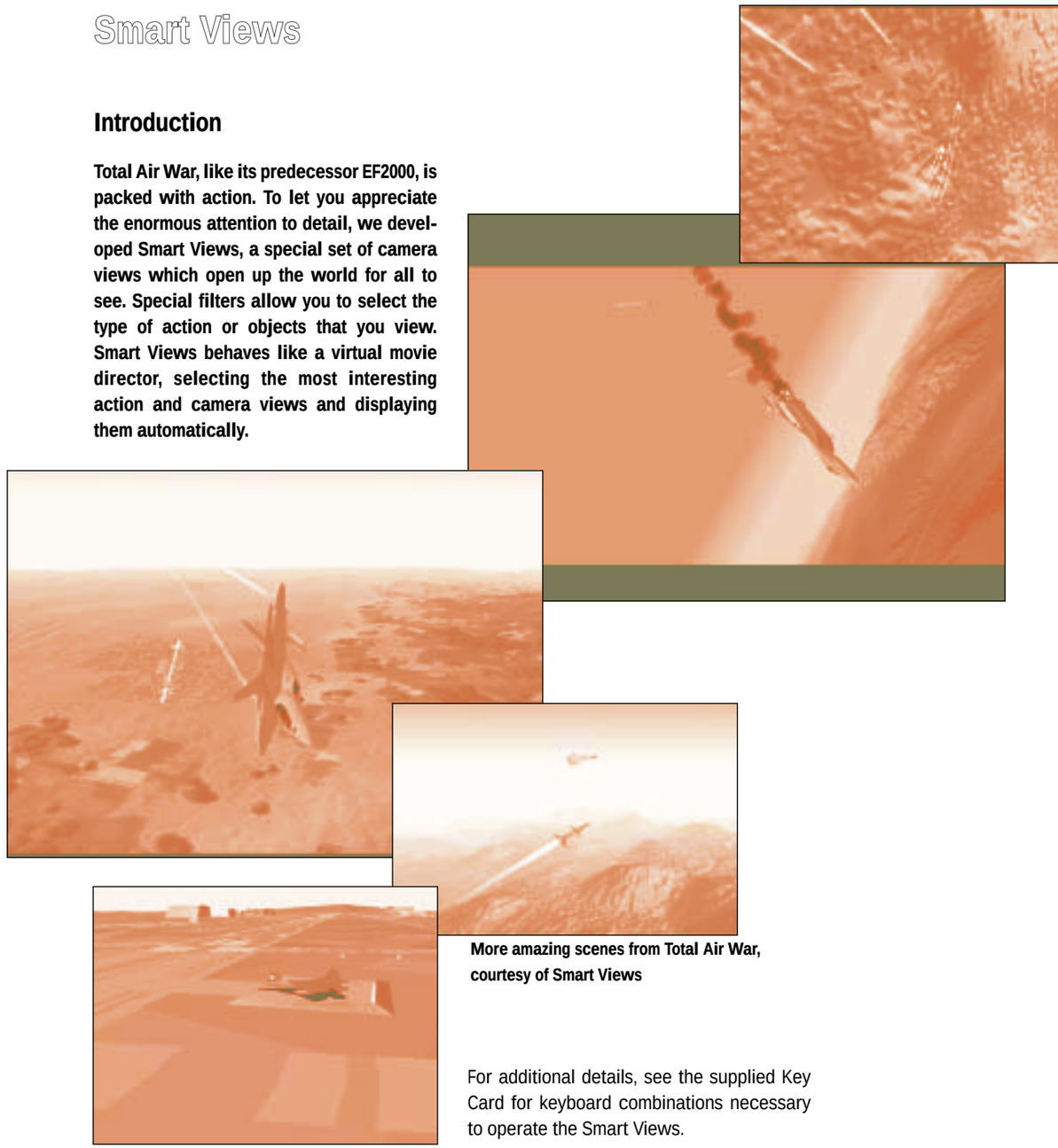
NUM 6 View Artificial Horizon MFD.

NUM 8 Return to normal F1 view of HUD.

Smart Views

Introduction

Total Air War, like its predecessor EF2000, is packed with action. To let you appreciate the enormous attention to detail, we developed Smart Views, a special set of camera views which open up the world for all to see. Special filters allow you to select the type of action or objects that you view. Smart Views behaves like a virtual movie director, selecting the most interesting action and camera views and displaying them automatically.



More amazing scenes from Total Air War, courtesy of Smart Views

For additional details, see the supplied Key Card for keyboard combinations necessary to operate the Smart Views.

The Smart Views Interface

When you press the F12 key, Smart Views mode will start and the interface will be displayed over the camera view briefly. The display is split into upper and lower panels, each containing several filters that can be changed. The F10 key will cycle through the types of object filter in the upper panel, while the F11 key will cycle through the allegiance filters in the lower panel.

The Smart Views Interface

In Smart Views mode the F9 key will lock your camera to whatever object you were viewing, through smart views at the time you press it.

Using Smart Views

The Smart Views cameras allow you to watch a mission separately from whatever role you were supposed to be playing. The cameras will move between views of interest according to the filters you have set and allow you to see the 'movie' of your mission in real time.

Smart Views Keys

The following keys control the Smart views system:

F12
Smart view menu system. A screen overlay will be shown for a few seconds.

F9
After pressing F12 toggle hold/unhold on current object.

F10
Choose object.

F11
Choose allegiance.

Z
View next object.

****
View previous object.

Shift Z
View next groups or flight.

**Shift **
View previous group or flight.

NOTE: It is advisable to engage your autopilot when using smart views during a mission. If you are killed, the Smart Views cameras will engage and continue showing the mission until it is 'timed out'.

Training

Introduction

TAW is based on the same simulation software that DID sell to military customers for real training applications. In the Training section, you will find a host of missions designed to familiarize you with the F-22 and AWACS aircraft, helping you to become proficient in the techniques of modern air combat.

The Training screen contains six training areas displayed on the top left of the interface, each containing pre-written missions. 'Flight Training' deals with the basics like take-off and landing, while 'Weapons Training' teaches how to target and launch your weapons. 'Free Flight' is a set of missions that will take you on an anticlockwise peacetime tour of the world, starting in the Yemeni mountains in the South. The 'Dogfighting Skills' section deals with training for combat, while 'Wingmen' teaches you how to make the most of your buddies. The 'AWACS Missions' is an area specifically to teach use of the AWACS commander.

NOTE: from the AWACS you will be able to enter and fly any F-22 on the AWACS display.

The Training Interface

As you select each training area, the missions within it are displayed underneath in a scrolling window, from where you will be able to select the individual missions by clicking on them.

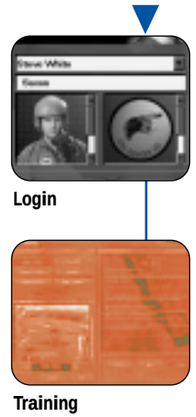
NOTE: the selected mission is highlighted in color.

The OK button
Pressing this button on the bottom left of the interface will start the selected mission.

The CANCEL button
Pressing this button will return you to the Main Menu.

Game Feature Options
To access game feature options from within the mission, press SHIFT O on the keyboard.

Information buttons
Below the Interface window on the right are six buttons that will display information in the window.



Login

Training

Practice makes perfect in the Training area

The Pilot Log button
Displays your campaign history and awards.

The Map button
Displays the world with your route overlaid.

The Briefing button
Gives a brief text description of the selected mission.

Practice difficult maneuvers such as air-to-air refueling

The Target View button

Displays information for the selected air-to-ground mission.

NOTE: this is only available for Weapons Trainng and Wingmen missions.

Features

The briefing displayed to you on mission selection will also be displayed in the map view, use the DEL key on the number keypad. For variety and to increase the training value, each of the missions contains objects and activities of interest other than those related to the basic training mission.

The skills that you as the game user learn within the Training section are imparted to each of your F-22 squadrons on entering the Campaigns. Though it is not necessary to complete this section before entering a Campaign, it will certainly help.

Missions are measured against a pre-set requirement for mission success and will be displayed to you as a percentage.

Multiplayer

Introduction

Multiplayer gaming in TAW is a great deal of fun. There are preset head to head, team play and co-operative missions for you to enjoy. Plus, you can create your own co-operative missions using the Custom Combat generator making the experience as dynamic as your own imagination. You will also be able to play TAW over various Internet Multiplayer Gaming services such as DWANGO, MPATH and Wireplay. There is a huge online community of virtual pilots waiting to do battle on the internet. Check out our website for hot links to virtual squadrons (http://www.did.com).

Note: We do not recommend using the partial install option for TAW multiplay.

The Multiplayer Interface

The following sections describe the TAW Multiplayer screens and what you need do at each one in order to setup a multiplayer game.

The Multiplayer Screen

Select a Service Provider

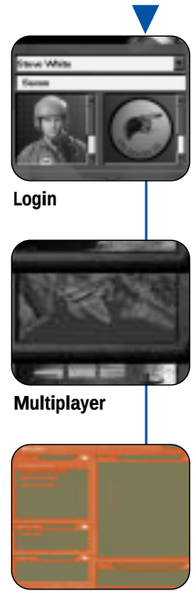
There should be a list of options in the Multiplay Client box. If there is not then DirectX may not be installed correctly. This list may also include options for other service providers (e.g. online game companies) that support DirectX. All players must select the same service provider in order to connect their machines together. Please refer to 'DirectPlay Multiplay Options' in this section for help in setting up each service provider.

Choose to Create or Join a Game

The TCP/IP, Serial and Modem service providers require the user to input parameters in order to locate the game host (i.e. the game creators machine). Please refer to 'DirectPlay Multiplay Options' in this section for help in setting up each service provider. When selecting IPX, a search for games will take place immediately.

Choose a Game

When there are one or more games in the 'Games In Progress' box you can select a game. This will either result in either 'Open' or 'Closed' being appended to the game name. If the game is closed then the game is not accepting any more players and you cannot join it. If the game is 'Open' then a list of current players will appear in the 'Current Players' box and the selected mission details will appear in the 'Game Details' box. You can then either join the game or select (and hence interrogate) another in the list.



Login

Multiplayer

Multiplayer Screen

The Multiplayer screen - chat to other pilots

Multiplayer

Error Messages

Please refer to 'DirectPlay Multiplay Options' in this section for help in setting up each service provider.

Game closed - unable to join!
This simply means that the selected game is not accepting any more players.

Failed to Open Service Provider.
The selected service provider is either not installed or has a problem. Check that it is installed correctly in the Network section of the Windows Control Panel.

This Service Provider is not Supported.
The selected service provider is not supported by TAW.

Could not create the game - Invalid Parameters.
A problem has occurred while creating the game. The selected service provider may be incorrectly installed or the parameters provided for a 'Serial' connection may be incorrect. There may also be a problem with the hardware being used (e.g. serial cable, network card or modem).

Connection timed out while joining game. Please try again.
Communication with the game host has discontinued.

Directplay error while joining game. Please try again.
A connection could not be made with the game host at the Directplay level.

Timed Out! Please try again.
A connection could not be made in the time period allowed.

Connection Lost!
You have been disconnected from the game.

No more new players!
The game at the stated address is not accepting any new players.

Please check IP address OR serial parameters and serial cable
This message means that either the IP address is invalid if TCP/IP is selected or that there is a problem with the serial connection.

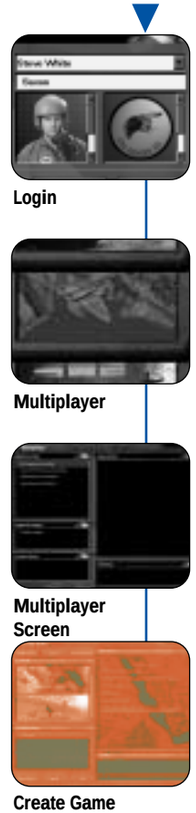
No Games Available
There are no games at the stated destination address. The game continuously searches for games until the 'cancel' button is pressed. If playing over the internet, wait a while, as the game may not yet have been setup by the game host.

Choose your battleground in the Create Game screen

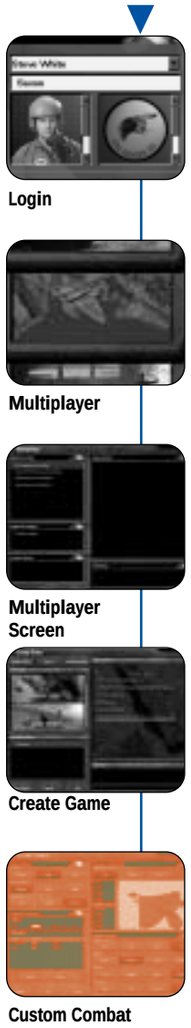
The Create Game Screen

In this screen you can either select one of the preset missions or create your own mission by selecting the Custom Combat option. There are three types of preset mission: head-to-head where it's every man/woman for themselves; team play where a maximum of four teams can battle it out; and co-operative where you work together to blow the AI enemy to pieces.

It is important to note that when the Custom Combat option is selected no more players can join the game and 'lurking' players (i.e. players interrogating the game) will be removed from the game.



Multiplayer



Design your theater of war in the Custom Combat screen

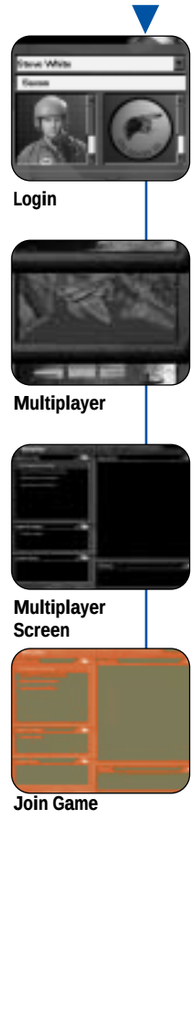
The Custom Combat Screen

Here you can build your own mission. You can select the number and type of planes, ships and ground based vehicles you want to fight against. You are also able to select the weapons package to use for each object. Please refer to the 'Custom Combat' section of the manual for help on how to set up a custom mission.

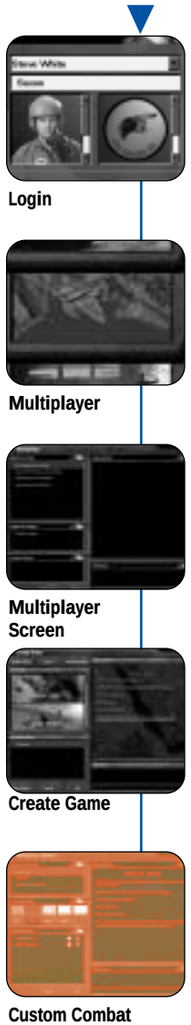
Spine tingling tension as you prepare for battle

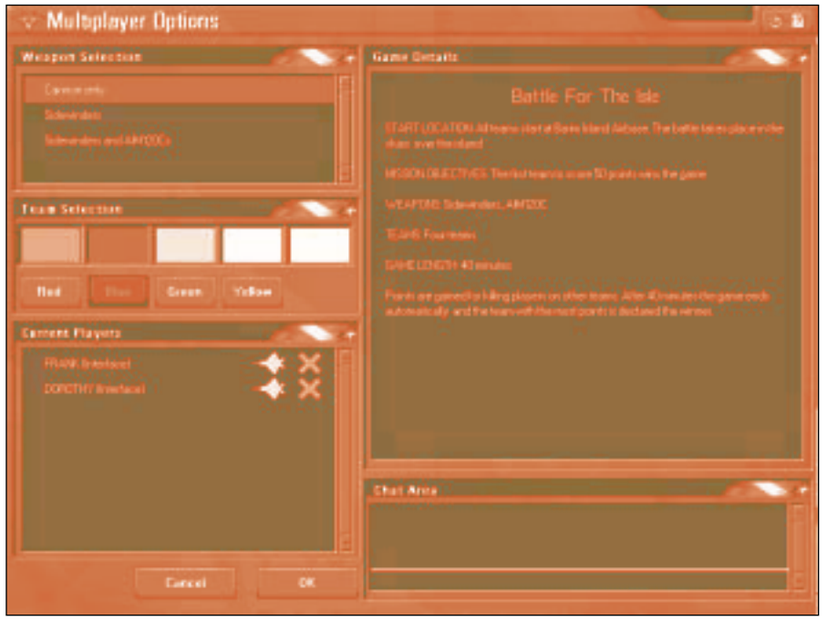
The Join Game Screen

Here players can chat to each other and are able to view the mission briefings for the missions that are selected by the game host.



Multiplayer





Choose your wingmen and load up your weapons

The Multiplayer Options Screen

This screen only appears if you select a preset mission. All players are able to select which weapons package they want to use and which team they want to be on.

DirectPlay Multiplay Options

This section describes the available options in the Directplay dialog boxes that you need to complete in order to connect to another computer.

The following connection methods will only work if you have them installed correctly otherwise an error message will appear. You can install service providers by selecting the Network (for IPX and TCP/IP) or Modem option from the Windows Control Panel.

IPX

Select this option for Local Area Network (LAN) multiplay. There is no dialog box for this service provider. If an error box appears please check that the IPX service provider it is installed correctly.

TCP/IP

This is the Internet standard but can also be used for multiplay on Local Area Networks (LANs). If you are joining a game then you must provide either the computer name or the IP address of the game creator. It is not recommended that you leave the field blank to search for games.

Serial

You must provide the following information in order to connect to another machine. It is important that both players choose the same settings in the Directplay dialog box. If the parameters are wrong then an error message will be displayed.

Port

You need to know which communication port (COM1, COM2, COM3 or COM4) that the serial cable is plugged into. If it is not apparent by looking at the back of your computer then the best way to find out is simply by trial and error.

Baud Rate

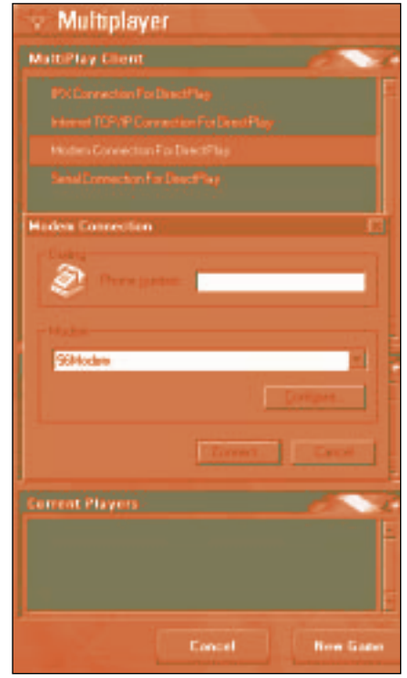
It is recommended that you use the fastest speed possible (minimum 14400 bps).

Stop Bits and Parity

Leave as default.

Flow

It is better to use RTS/DTR hardware flow control but it largely depends on which cable you are using.



Modem

You must first select a Modem from the given list of installed modems. If you are joining a game then you must also provide the phone number of the machine you want to dial into. Set the speed on both machines to the fastest speed of the slower modem. Make sure that both machines have the same maximum speed setting.

Most of the configuration settings can be left as default. If you have a modem that enables you to turn off error control then this may help overall performance.

When playing custom combat missions over low bandwidth media it is advisable to be prudent with the amount of movable objects in the world as this will have a direct impact on the performance of the game.

Multiplayer Internet Gaming

Playing TAW over Kali95.

Please find below a number of recommendations that will help improve gameplay over Kali95.

Another opponent bites the dust in TAW Multiplay

Low ping times are best! Ideally the ping time to each player should be at most 500ms. Turn chat mode off and ensure that all chat windows are closed before starting the game. Receipt of chat messages during the game will minimize the game.

It is advisable to install a full version with music turned off.

When selecting options within each screen, give the game time to respond. Over zealous mouse clicking will only make things worse!

When creating a Custom Combat mission don't overload the world with objects (including missiles!).

Allow Kali to drop packets to speed up game.

MPATH
www.mplayer.com

Wireplay
www.wireplay.com

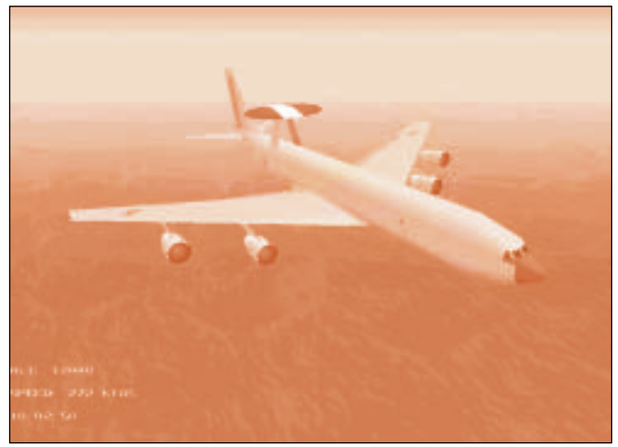
Dwango
www.dwango.com

Airborne Warning And Control System (AWACS) Command

Introduction

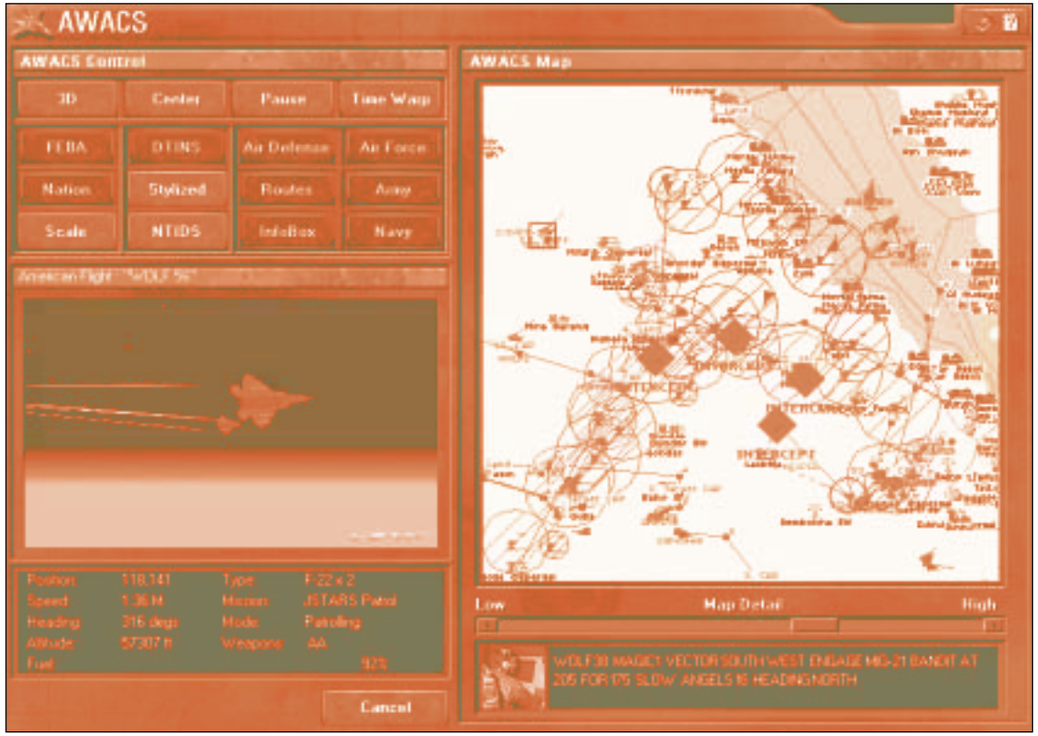
The E-3 Sentry AWACS aircraft is a fundamental part of the Command, Communications and Control (C^3) system allowing the AWACS commander to control the localized air war in a way favorable to him. The AWACS looks after the flight control of all aircraft within his radar view, identifies and prioritizes air threats, organizes and monitors Combat Air Patrols (CAP) and flight Interceptions. Within this game the AWACS can redirect Close Air Support (CAS) missions based on data received from ground commanders and the E-8 Joint Surveillance Targeting And Reconnaissance System (JSTARS) aircraft.

The AWACS radar is optimized against air threats and can detect the presence of flights at ranges of up to 250 miles depending on the altitude and radar cross-section of the flight. Stealthy flights may remain undetected or unidentified until they are much closer. At the edge of the radar's range, a flight will appear as an unknown contact, the type and number of planes cannot be detected at ranges greater than 200 miles. At ranges less than 200 miles the AWACS radar will be able to produce basic information about the type and number of planes in the flight and will be able to identify the flight as hostile, friendly, or neutral. Using a combination of ELINT (electronic Intelligence), Link-16, radar and visual identification methods the AWACS can produce detailed information such as weapons loads on flights within ranges of 150 miles.



The radar can also see ships and to a lesser extent ground vehicles, although to get full ground coverage a JSTARS aircraft will need to be available to data-link with the AWACS. The AWACS is available in relevant missions of the Training and Campaign sections of TAW.

AWACS



The AWACS Command Interface

The AWACS interface is divided into a left and right panel containing five components: The Control Panel; The 3D World Window; The AWACS View Information Window; The AWACS map Window; and The AWACS Message Window.

The Left Panel

The Control Panel

The AWACS Command Interface consists of sixteen buttons. These control the style and content of information displayed in the AWACS Map Window and allow the player to accelerate or suspend the game.

3D
Toggle the 3D map display in the AWACS Map Window.

Pause
Suspend the game. When Pause is selected, the text 'Paused' will appear in the AWACS 3D World Window.

Center
Reset map to combat zone in AWACS training mission.

Time Warp
Increase the speed at which the game runs. When Time Warp is selected the text "Time Warp" will appear in the AWACS 3D World Window.

Scale (Training Missions only)
Display a scale in nautical miles at the bottom of the AWACS Map Window.

Targets (Campaign only)
Display current strategic objectives.

FEBA
Display the Forward Edge of Battle Area.

Nations
Displays the colored map and nation names in the AWACS Map Window (on by default).

DTINS
Display the DID Target Interaction Symbology (DTINS) icons and text (on by default).

Stylized
Toggle between Point (default) Symbology and Stylized symbology. This button is disconnected when NTIDS are selected.

NTIDS
Toggle NATO Target Identification Symbology (NTIDS). This button will override your choice of Point/Stylized symbology.

Air Defense
Display Surface to Air Missile launchers (SAMs), Early Warning Radar (EWR), Radar and Communications sites. When the 3D AWACS Map is selected, this displays SAM umbrellas.

Air Force
Display all airbases and airfields (on by default).

Routes
Display allied aircraft flight paths and waypoint routes.

Army
Display all Military bases and any known or allied ground forces. An E-8 JSTARs aircraft must be airborne to display detailed ground force information.

Navy
Display all Naval bases and any known or allied Naval forces.

Information Box
Display the flight information boxes alongside the flight currently under the mouse cursor in the AWACS Map Window. This

AWACS

information is also presented in the AWACS View Information Window.

The AWACS 3D Window

A 3D world view of the currently selected map object is displayed below the Control Panel Buttons.

The AWACS View Information Window

Below the 3D window is the AWACS View Information Window. This will list relevant information about the flight or object currently being viewed in the AWACS 3D window. For flights that are unknown or out-of-range of the AWACS no information will be available.

Cancel Button

Pressing the Exit button will return you to the Training or Campaign menu depending on where you started from.

The Right Panel

The AWACS Map Window

The AWACS Map Window displays the area of the world currently within AWACS radar range. It displays the components of the battle that the player has selected with the filters available in the AWACS Control Panel. These can include all of the allied air, land and sea forces. Plus all the enemy and neutral forces within range of the AWACS. The airbases, Military and naval bases in theater can be displayed. Additional information for allied aircraft can be visualized, including CAP and CAS patrol areas, flight paths and waypoint routes. Friendly objects are displayed green, Enemy objects are displayed red, neutral objects are displayed blue and objects about which little is known will be displayed orange1.

Viewing Flights and Objects using the AWACS Map Window

Any item displayed on the map can be viewed by simply moving the mouse cursor over the icon in the AWACS Map Window and clicking with the left mouse button. These objects include aircraft flights, ground based vehicles, ships, airbases, army bases, ports, SAM installations and radar sites.

If the object is part of the allied force, it will appear clearly in the AWACS 3D World Window. However, if the object is unknown and the player is yet to perform reconnaissance in that region, the image in the AWACS 3D World Window will appear distorted and noisy. If a flight is destroyed whilst being viewed in the AWACS 3D window, the view remains focused around the last recorded position of that flight. In order to update this, the player must select another flight in the AWACS window.

Moving Around the AWACS Map Window

2D Map Zoom and Control

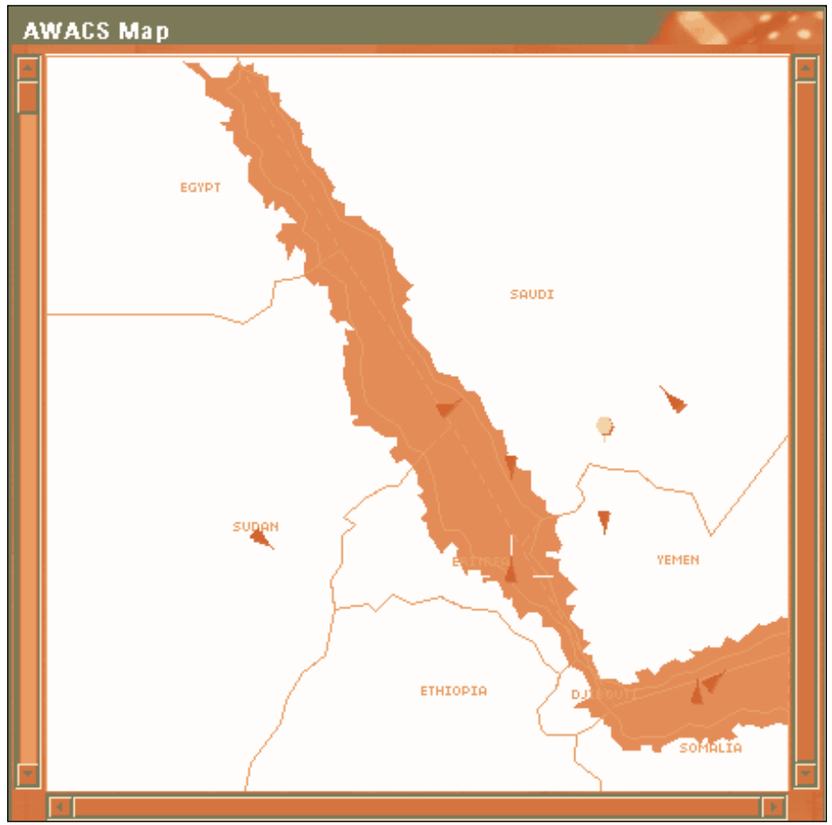
When the AWACS map is in 2D mode the map can be controlled by use of the SHIFT key, plus the left and right mouse buttons.

Selecting Items

The left mouse button is used to select items on the map.

Zooming the map

To zoom into the map the mouse cursor must be on the AWACS map. Place the mouse



cursor above and to the left of the area which you want to zoom into, hold the SHIFT key and press the left mouse button and while continuing to hold it down pull out a zoom box encompassing the area that you want to zoom the map to. Then while keeping the SHIFT down, release the left mouse button to carry out the zoom.

The left mouse button can now be used to move the zoomed map by pressing and holding SHIFT on the keyboard, move the mouse cursor to the center of the area which you desire to move towards and then press the left mouse button.

To zoom back out of the map, press SHIFT on the keyboard and the right mouse button while the mouse cursor is anywhere on the map, to zoom out one stage. To zoom fully out to the full size map, continue to hold the right mouse button until the zoom has taken place.

3D Map Zoom and Control

When the AWACS map is in 3D mode the map can be controlled by use of the keyboard SHIFT key, plus the left and right mouse buttons.

AWACS

Selecting Items

The left mouse button is used to select items on the map.

Zooming the map

To zoom into the map place the mouse cursor on the AWACS map, hold the SHIFT key and press the left mouse button . Moving the Mouse forwards and backwards will alter the zoom.

Rotating the map

To rotate the map press and hold SHIFT on the keyboard, then hold the right mouse button down and move the mouse cursor to the right to achieve a clockwise rotation, or move the cursor to the left side for a counter clockwise rotation.

Changing the map zoom focus

To change the focus of the zoom, press and hold SHIFT on the keyboard, hold down both of the mouse buttons and move the mouse cursor from one side to the other, or from top to bottom.

Commanding flights through the AWACS Map Window

The AWACS Commander has the power to perform a wide variety of tasks in the control of the tactical Air War:

- Identify and prioritize air threats.
- Organize and monitor Combat Air Patrols (CAP).
- Assign and update flight Interceptions including visual identification, shadow and engage-to-kill tasks.
- Vector flights to refuelers or to land.
- Assign allied flights to aid other allied flights in distress.
- With assistance from the E-8 JSTARs aircraft, vector Close Air Support (CAS) flights to kill mobile ground targets such as SAMs, SCUDs and enemy tanks.

The command generation system is context sensitive, only allowing the Commander to send valid commands to Allied flights. Commands that are valid but are not currently available will either produce a negative response from the command generation system or from the flight itself.

Note: In order to make it clear which flights are being controlled and targeted in the AWACS Map Window, the DTINS button must be selected.

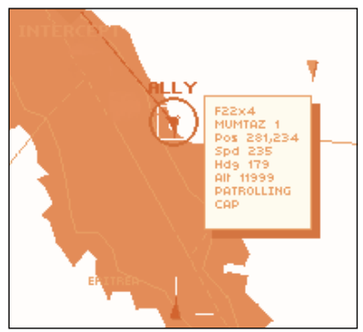
Command Generation

Commands are generated by the following procedure :

1. Select an allied flight by moving the mouse over the flights until a suitable flight has been highlighted.

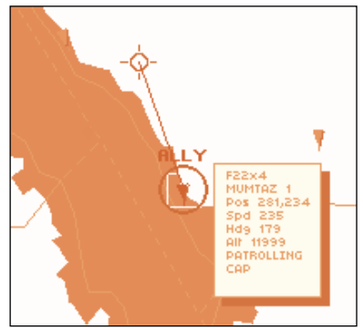
In the example above an Allied CAP flight is being chosen for a task. Notice the green circle DTINS icon to indicate an allied flight.

2. Use the left mouse button to select that flight for a task.



You may notice that the CAP flight is armed with Air-to-Air weapons making it suitable for Intercept tasks. This information can be seen in the flight information box below the 3D window.

3. Move the mouse to either a new map location (in the case of relocating patrol missions) or onto another flight. This action will produce an icon and text over the new flight describing the command that will be generated if the left mouse button is released. (For details of commands and icons see table below).



Here the CAP flight is being dragged to an Enemy flight producing a red diamond.
DTINS icon to indicate that an Intercept-to-Kill task will be sent to the Allied flight if the mouse is released.

4. To Send the command, release the left mouse button over the Flight.

To Cancel the command, return the mouse cursor to the original flight location and release the left mouse button. The command has been sent to the Allied CAP flight to intercept and kill the enemy flight. The Allied flight responds to the AWACS and sets up its intercept vector to the enemy flight. This is illustrated as a dashed line modifying the current flight way-point route. The intercept vector is the point in space where the two flights will meet if they maintain their current headings and speeds. The intercept vector is updated as these change.

AWACS

A successful command will produce a text confirmation displayed in the AWACS Message Window and if speech is activated, an audible message. The response from the Allied Flight can be both seen and heard.

Commands from Allied Flights to Allied Flights

The ESCORT command

As AWACS Commander, you can tell any Allied flight armed with Air-to-Air weapons to escort any other Allied flight. When the escort command is available a green circle will appear over the flight to be escorted.

The REFUEL command

If an Allied flight requests fuel, the AWACS Commander can drag and drop that flight to any patrolling allied refueler within range. If the refuel command is available a semi-filled circle will appear over the refueler.

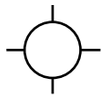
Note: Allied flights dragged to a refueler will be told to escort the flight unless they have previously requested refueling, or are low on fuel (those that are capable of mid-air refueling).

The LAND command

If a flight requests landing or you simply want to force a flight to land, then as AWACS Commander you can drag and drop the flight to any Allied airbase. If the Land command is available, then an inverted triangle will appear over the airbase.

The MOVE PATROL command

The move-patrol command is only available to flights that are in patrol mode (check the flight information box to see what mode the flight is in). The flights that will go into patrol mode are CAP, CAS, AWACS, JSTARS, REFUELER and some ELINT. To move a patrol position simply drag and drop the mouse to the new patrol position. While the patrol flight is being dragged and dropped to its new location, a small circle with crosshairs will appear attached to the mouse.



Commands from Allied Flights to Neutral Flights

The SHADOW command

As AWACS Commander you can tell any Allied flight to shadow any Neutral flight. As Neutral flights should normally be of little danger to our alliance, the shadow command will merely make the Allied flight follow the Neutral flight closely. If the Neutral flight becomes aggressive or if it violates Allied airspace, the Allied flight may then take action to destroy it. If the shadow command is available, a blue DTINS diamond-with shadow symbol will appear over the Neutral flight.

Commands from Allied Flights to Enemy Flights

The INTERCEPT command

Any enemy flight can be intercepted by dragging and dropping any Allied flight armed with Air-to-Air weapons onto it. The intercept command will force the Allied flight to engage in combat with the enemy flight. If the intercept command is available a red DTINS solid diamond will appear over the enemy flight to be intercepted.

Commands from Allied Flights to Enemy Ground Vehicles

The Strike Command

As an AWACS commander you can task an allied flight with suitable Air-to-Ground weapons to strike an enemy ground vehicle.

Commands from Allied Flights to Unknown Flights

The VIS-IDENT command

Flights that are on the extremes of the AWACS radar's coverage will appear on the AWACS map display as unknown contacts. These flights are too far away to be positively identified by the AWACS but an Allied flight can be dragged and dropped onto them and forced to visually identify the flight for the AWACS. If the vis-ident command is available an orange DTINS diamond will appear over the unknown flight which is to be identified.

Information Adjust Slider

Below the AWACS Map Window is the Information Adjust Slider. Moving the slider with your mouse cursor will alter the amount of information displayed in the AWACS Map Window.

The AWACS Message Window

Situated beneath the AWACS Map Window, the AWACS Message Window displays messages sent between the AWACS Commander and Allied flights in Theater. These messages can be both read and heard.

Looking at the diagram above, 'IRON 2' refers to the flight call sign, 'MAGIC 1' refers to the AWACS call sign, 'VECTOR NORTH' refers to the direction that the flight is required to take to acquire the target. The 'VIS-IDENT' command instructs the flight to visually identify the target. The remainder of the message gives details about the target. Clicking on the colored image will zoom the AWACS map to the sender's location.

AWACS & Difficulty Settings

In easy and medium difficulty targets are highlighted with a red box and allied F-22s are colored light green.

Mission Completion

AWACS Training missions end when the last allied AWACS in theater is destroyed or lands at an airbase.

AWACS

AWACS NTID Symbology

	Allied (Green)	Enemy (Red)	Neutral (Blue)	Unknown (Orange)
Aircraft				
Flight				
Ship				
Ship Group				
Helicopter				
SAM Site				
Ground Vehicle				
Ground Vehicle Group				
Air Base				
Army Base				
Comms Site				
Port				

AWACS Stylized Symbology

	Allied (Green)	Enemy (Red)	Neutral (Blue)	Unknown (Orange)
Aircraft				
Flight				
Ship				
Ship Group				
Helicopter				
SAM Site				
Ground Vehicle				
Ground Vehicle Group				
Air Base				
Army Base				
Comms Site				
Port				

AWACS Point Symbology

	Allied (Green)	Enemy (Red)	Neutral (Blue)	Unknown (Orange)
Aircraft				
Flight				
Ship				
Ship Group				
Helicopter				
SAM Site				
Ground Vehicle				
Ground Vehicle Group				
Air Base				
Army Base				
Comms Site				
Port				

Online Help

Introduction

One of the great benefits of Windows 95 is the refined system for providing online help. Based on the same information as the manual, online help adds the benefits of 'hot-links' to help you navigate your way through topics, and interactive graphics that aid understanding of the way systems work. In addition, TAW offers instant supplementary help in the form of 'tool-tips': simply leave the mouse pointer over a button and a small text explanation of the buttons function will appear.

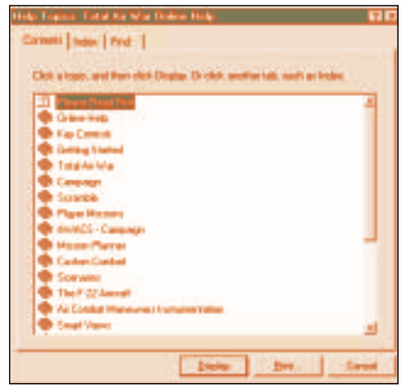
Online graphical help is a handy feature when you are learning how to use TAW for the first time. It saves reaching for the manual each time you want to learn about a feature, but offers the benefits of interactivity. Topics are linked together by 'key words', which let you explore a subject that might be explained throughout several different sections of the help file.

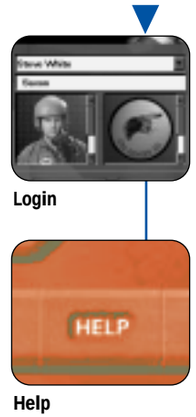
For additional details, see Online Help in the Main Interface of TAW (Help button).

The Online Help Interface

The Total Air War Online Help uses the windows help system which has now become a de facto standard for PC software.

Where possible, we have included graphical elements to help increase understanding of certain subjects, such as the avionics.





Login

Help

Using Online Help

When you first load TAW Online Help, you will be presented with the 'Contents' listing, represented by a series of 'Books'.

By clicking the tabs at the top of the window you can access an index of all the documents in the help file, and browse a fully customizable search database with Find.

Should you decide to use the interface full-screen and you want to access the help file easily, try opening the help file full-screen and then swapping between the help file and the simulation using ALT TAB.

Index facility

This will allow you to type in a word, after which you will be shown the document titles that contain that word.

Find

This works in much the same way as 'Index' but offers more power and flexibility by searching through entire documents.

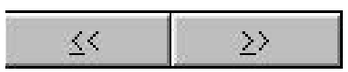
Documents
To access a document, open an appropriate book and select a document from inside. At the top of the document window you will be presented with a new set of buttons labeled **Help Topics**, **Back**, **Print**, **<<** and **>>**.

Help Topics - shortcut T
This will return you to the main contents list as described above.

Back - shortcut B
Clicking 'Back' will return you to the previous document that you were reading.

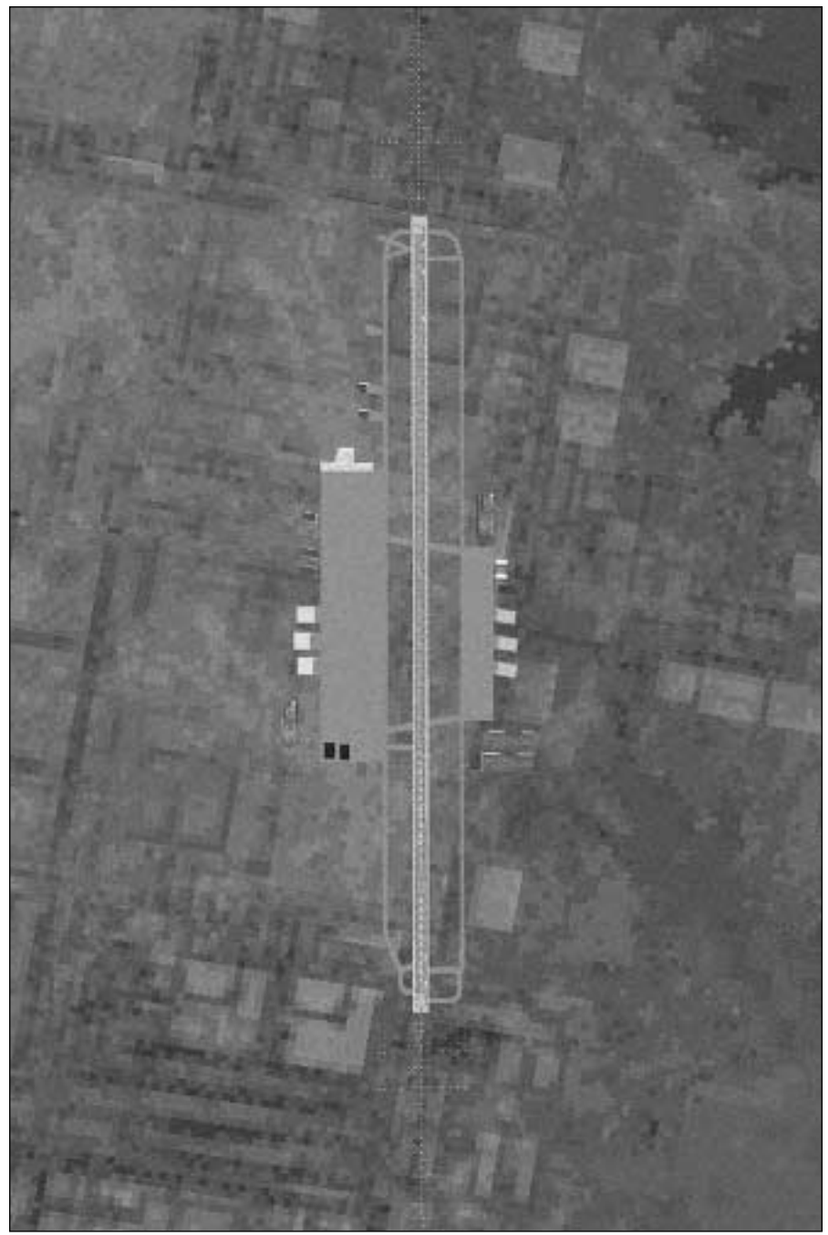
Print - shortcut P
To make a printed copy of the current document click this button.

NOTE: you must have a printer connected for this function to work, or alternatively Windows 95 will allow you to print to a file (see your Windows 95 documentation for more details).



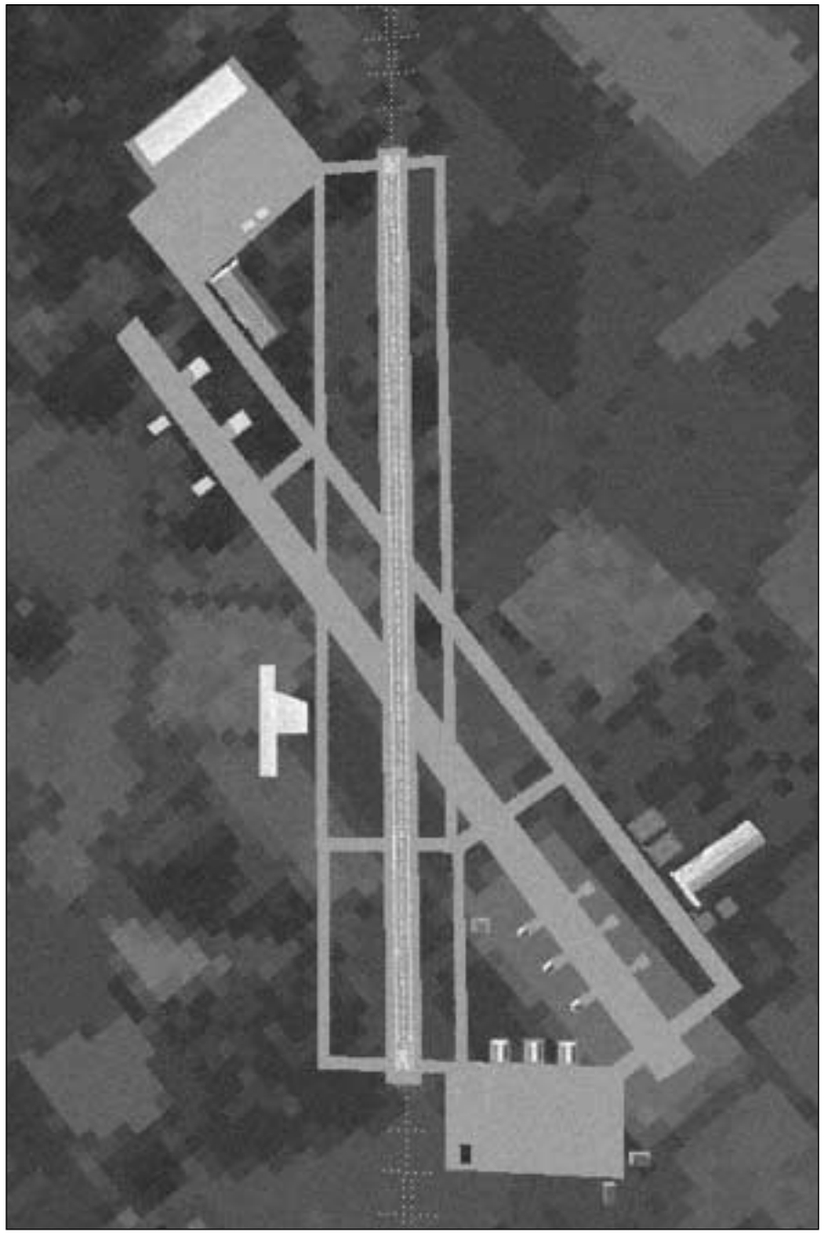
<< >> - shortcut < and >
These two buttons will allow you to move backwards or forwards through the entire help file in sequential order.

Aden Airport

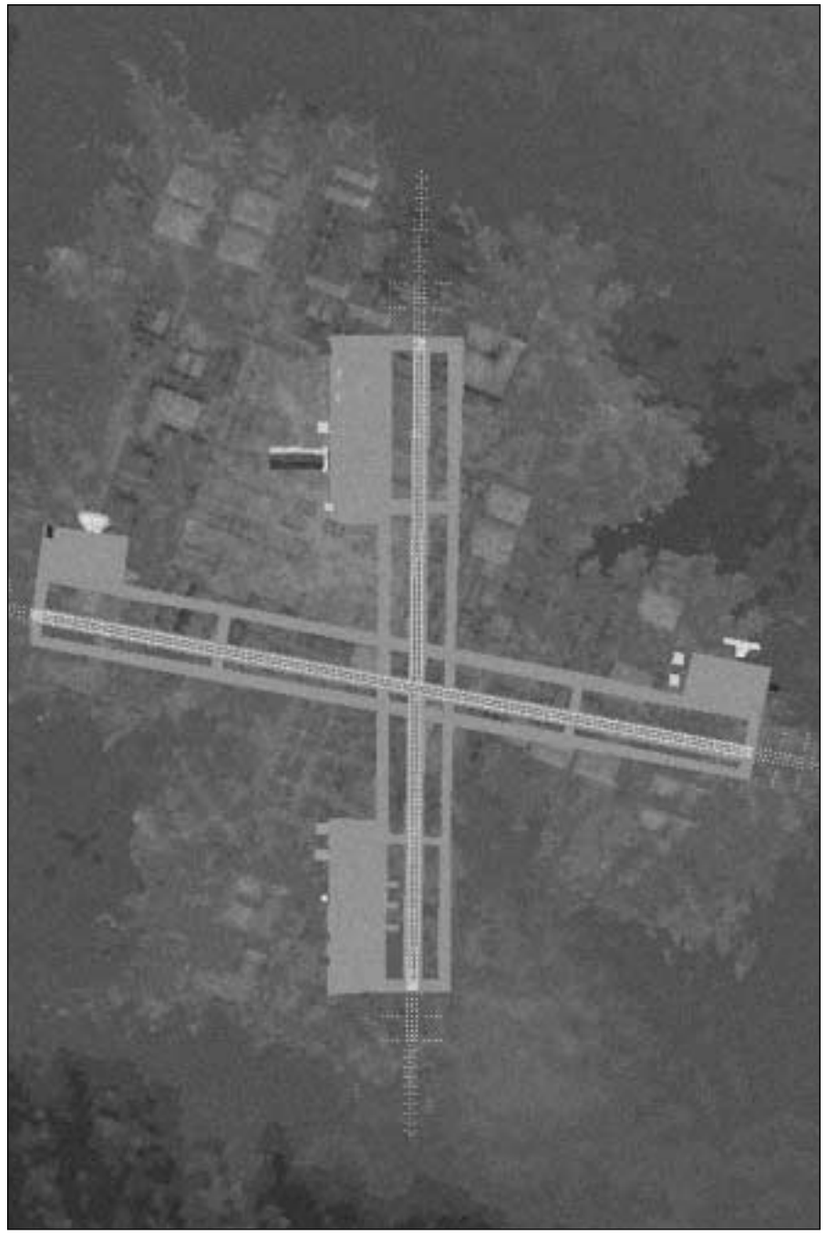


Airfields

Asyut Airport

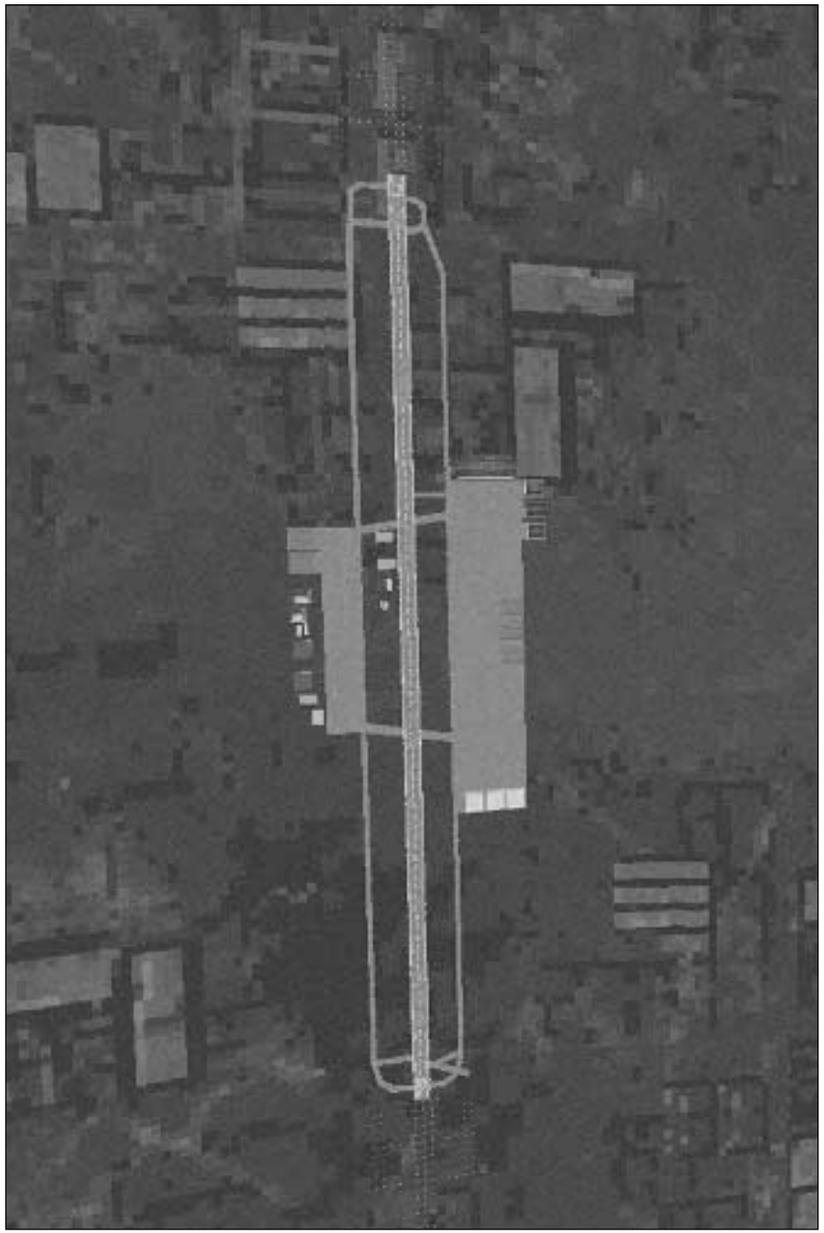


At Taif Airport

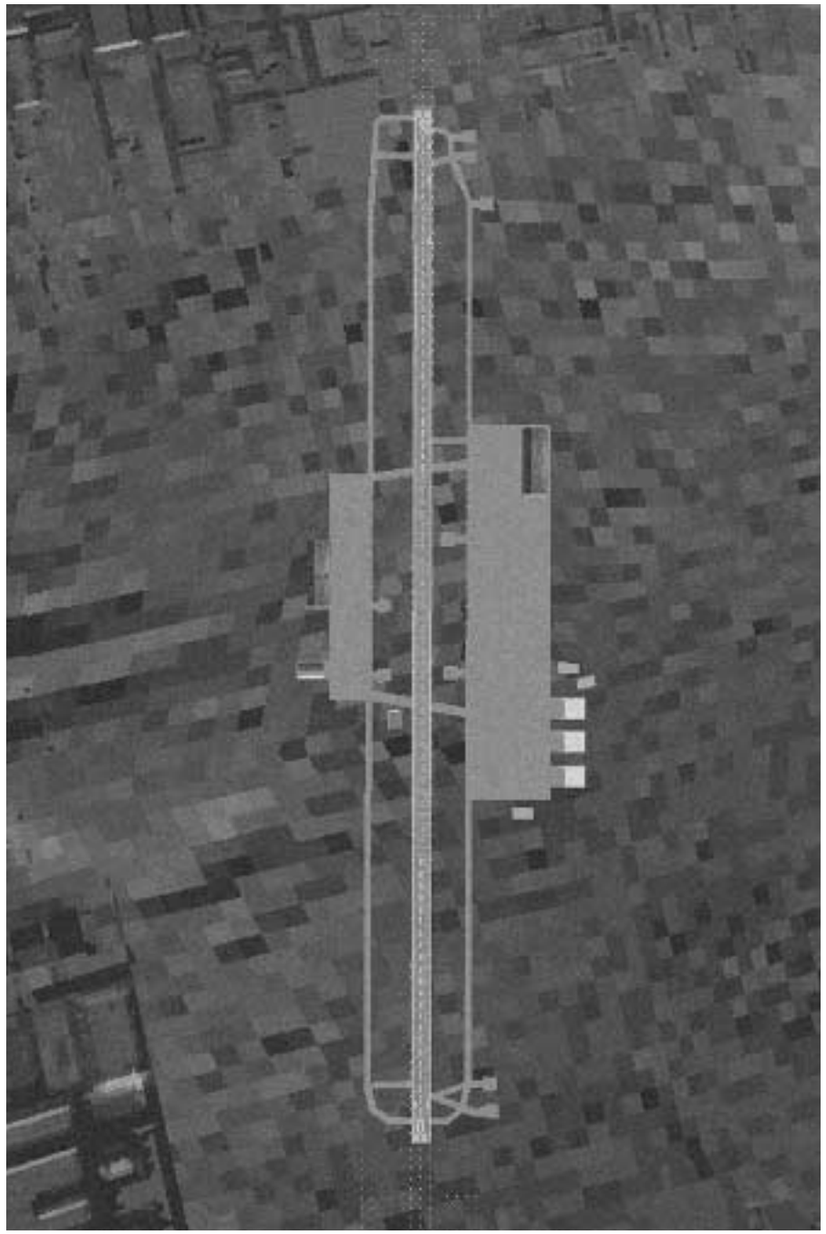


Airfields

Djibouti International Airport

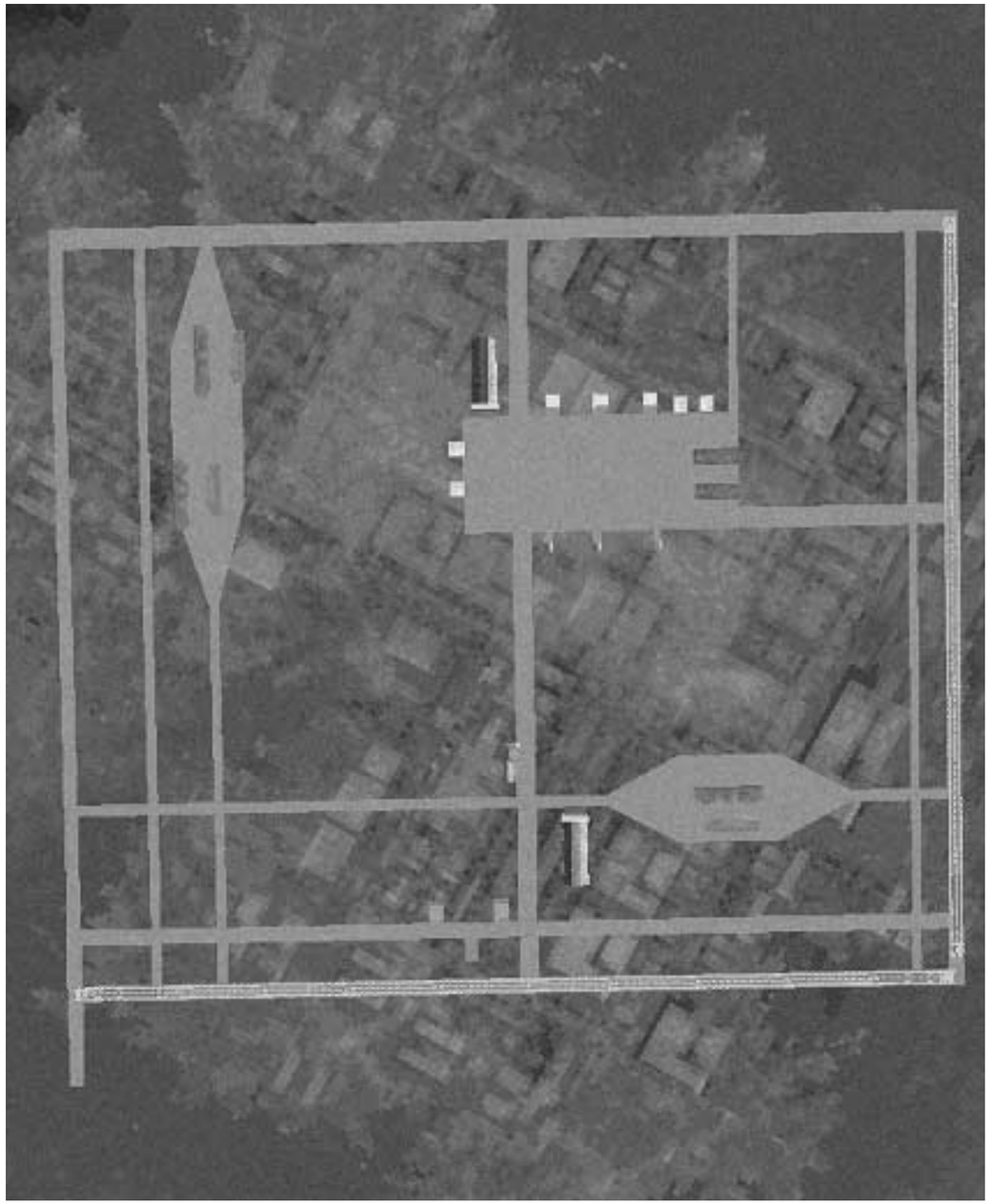


Jeddah Old Airport

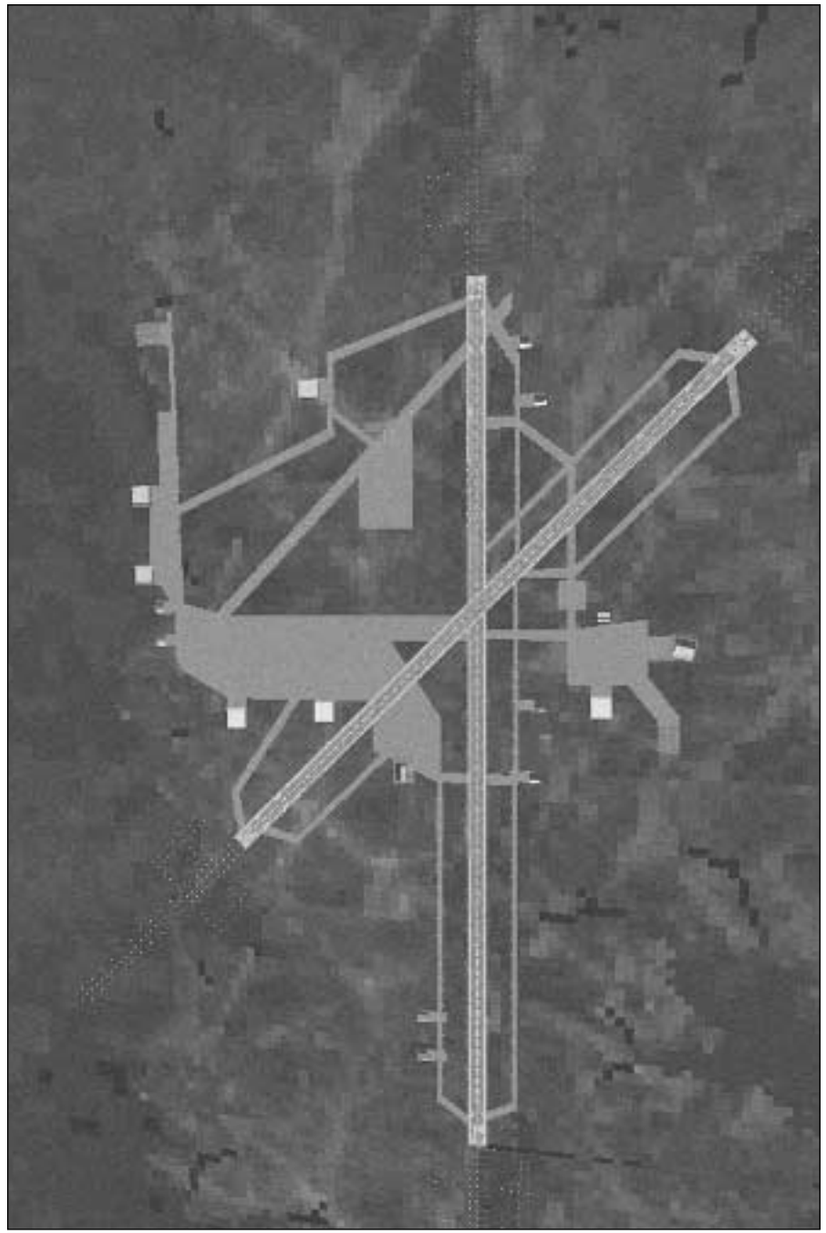


Airfields

Khamis Mushayt Airbase



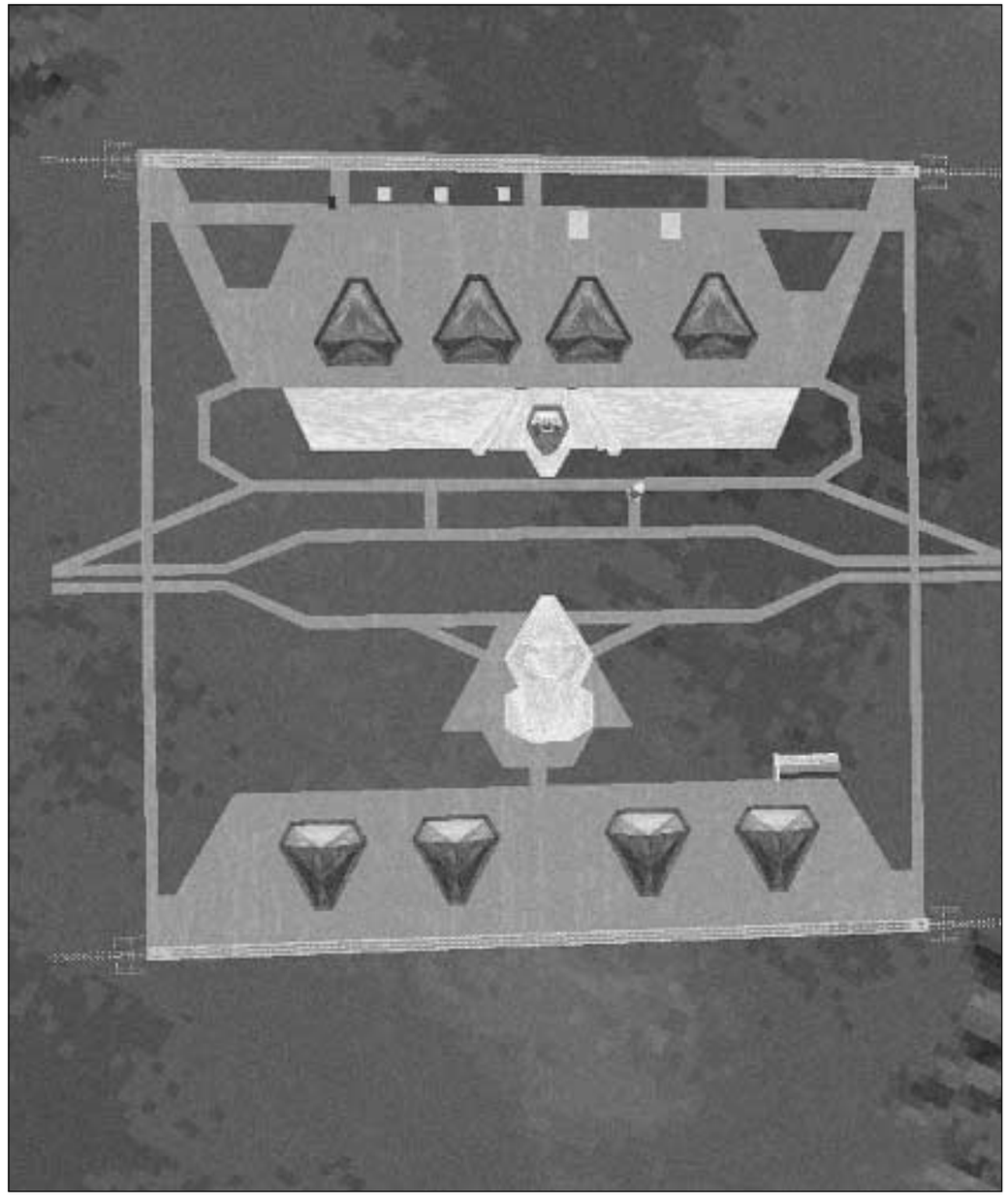
Khartoum Airport



Airfields

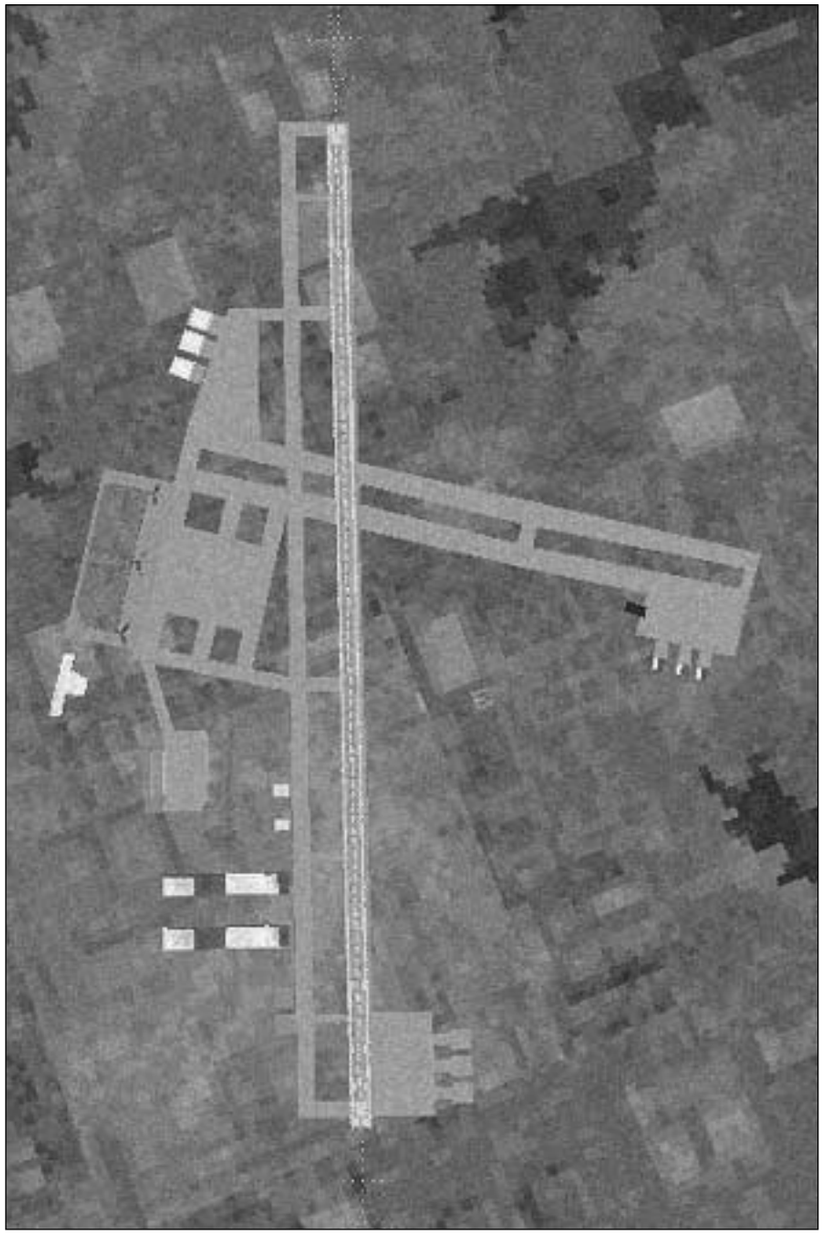
King Abdul Int. Airport Jeddah / Mecca

King Khalid International Airport - Riyadh

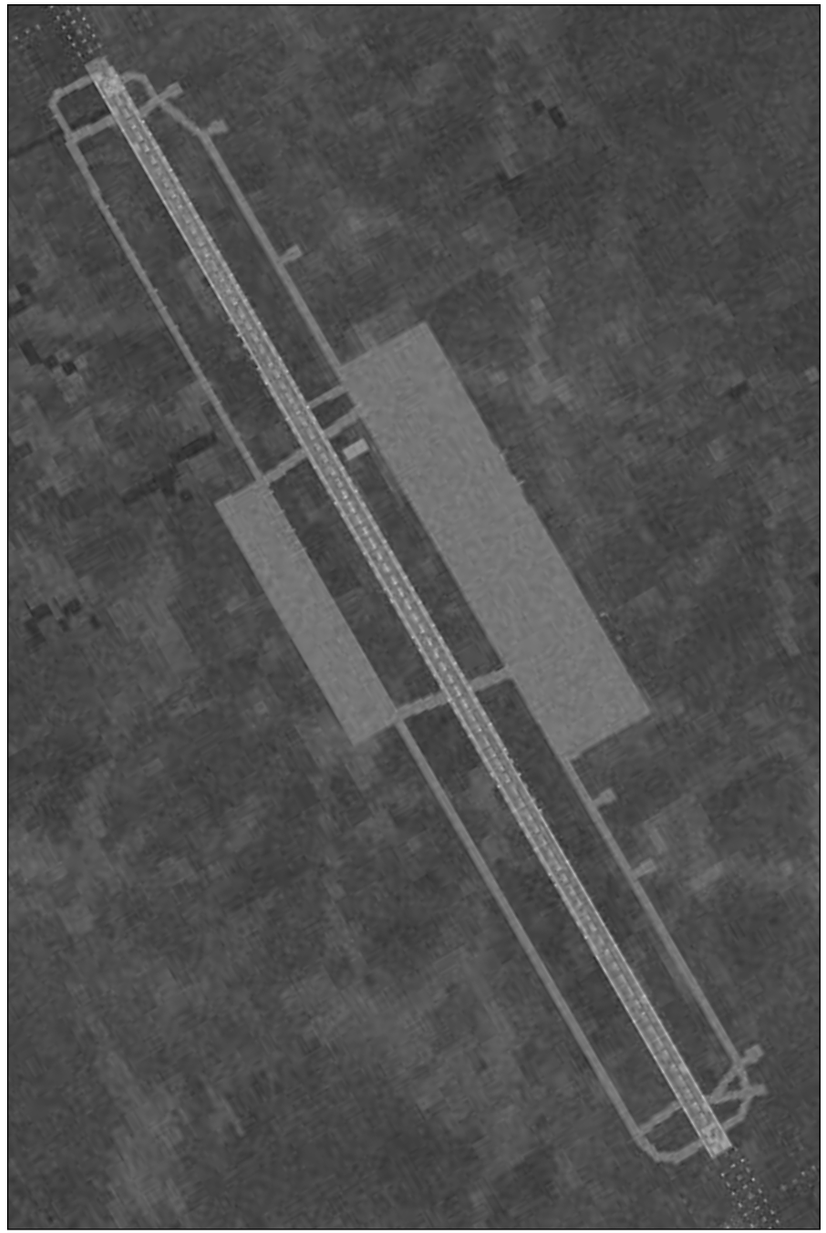


Airfields

Luxor Airport

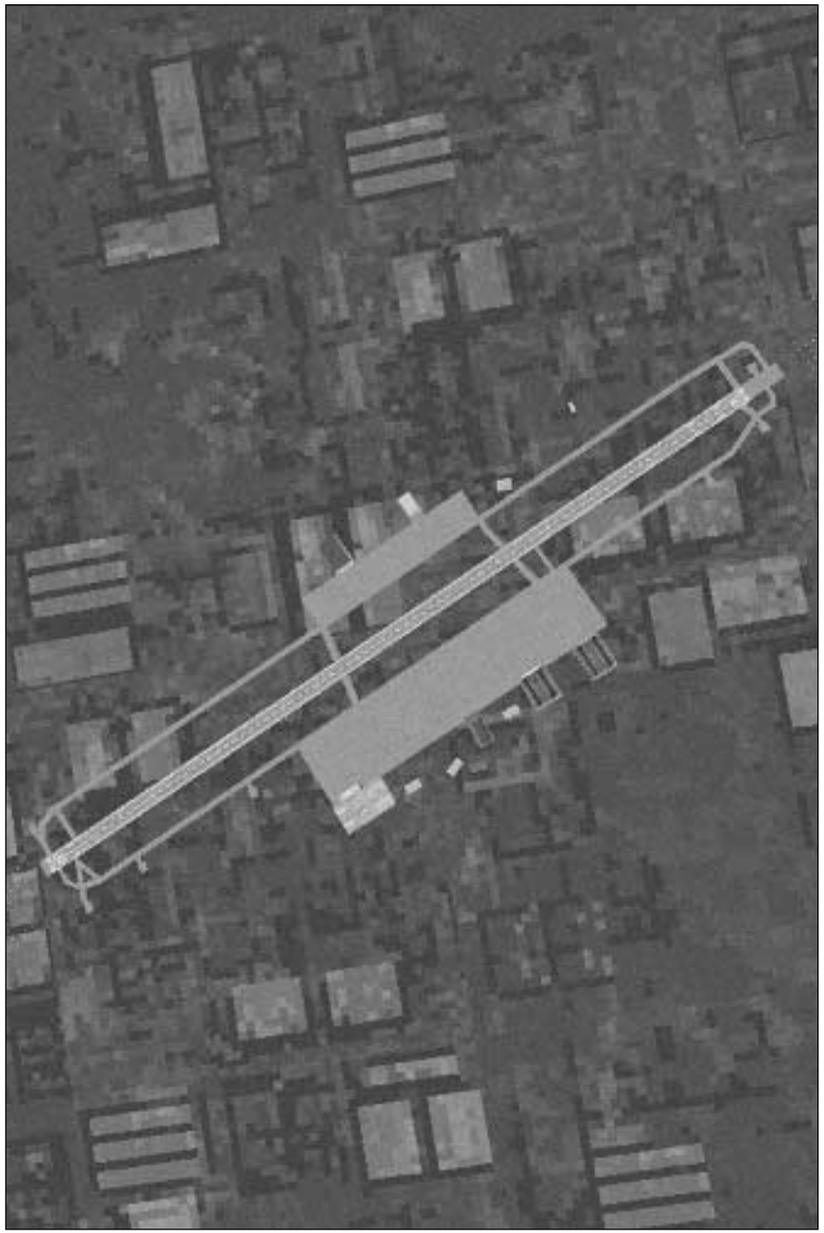


Provincial Dispersal Airbase

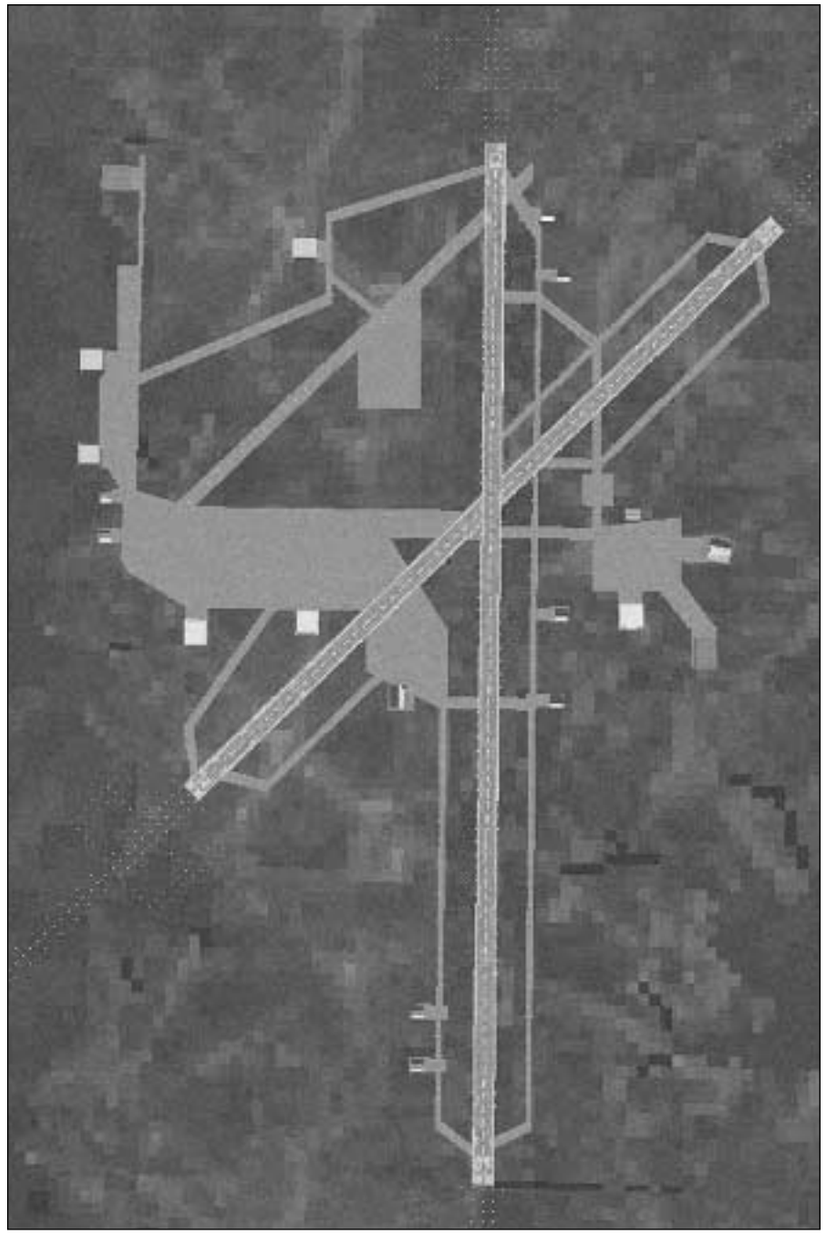


Airfields

Small Provincial Airbase (Sinprov)

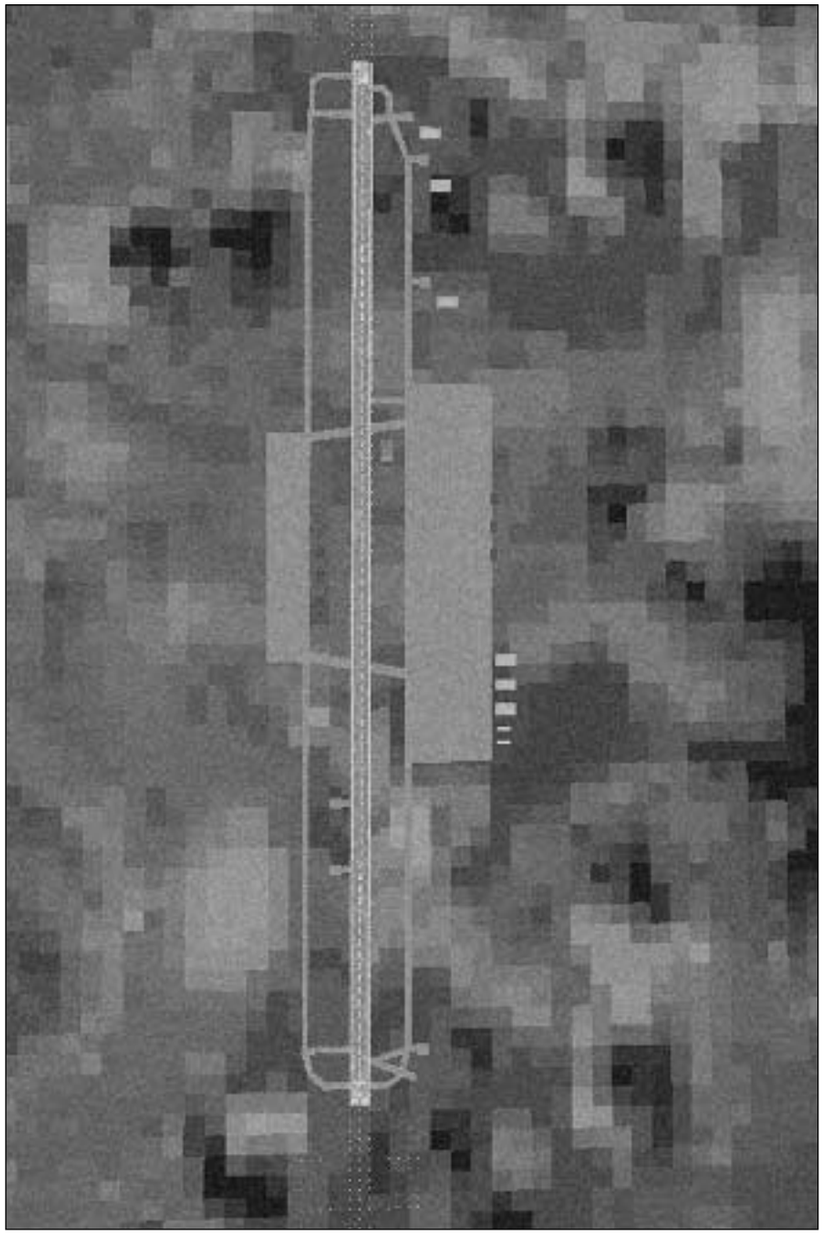


Large Provincial Airbase (Um Durman)

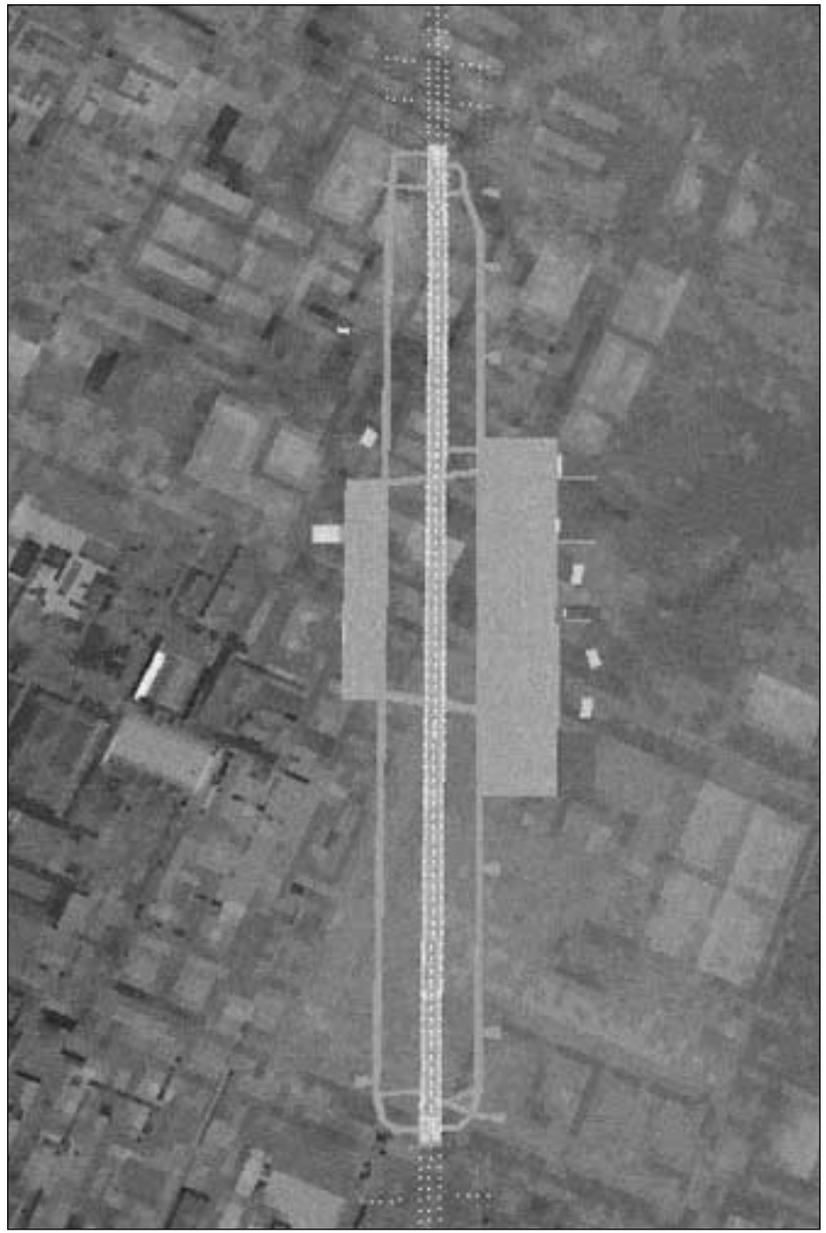


Airfields

Provincial Island Airbase (Barim)



Riyadh Military Airbase



Ground Vehicles

Tanks

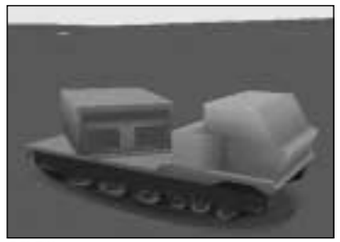

M-1 Abrams

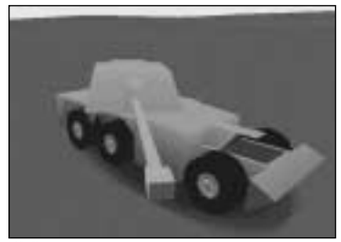

Challenger II

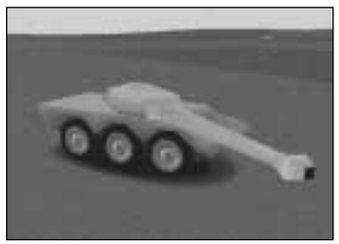

T-80

Self Propelled Guns


M-109


MLRS

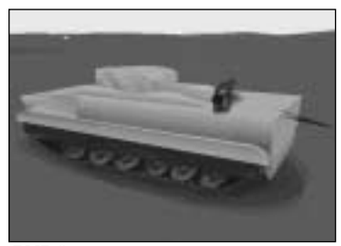

G-6


AMX-10RC

Armored Personnel Carriers

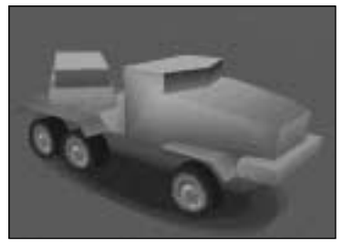

M-163 Vulcan

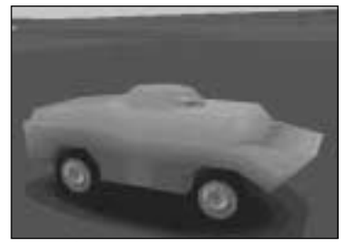

Warrior


BMP-3

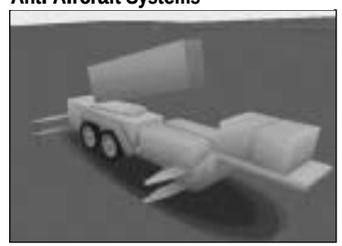
Recognition

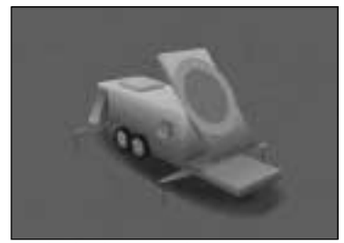
Ground Vehicles

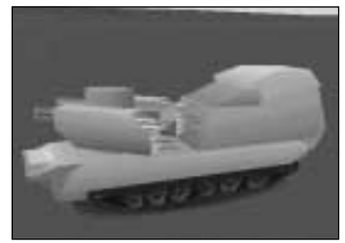

BMP-3BMZ


BRDM-2

Anti Aircraft Systems


Patriot (Missile System)


Patriot (Radar System)

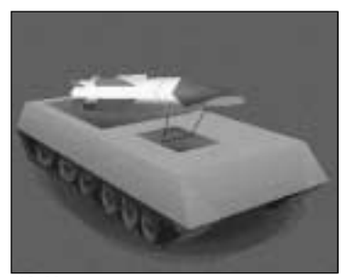

Jernas


Chapparal


Roland


Crotale

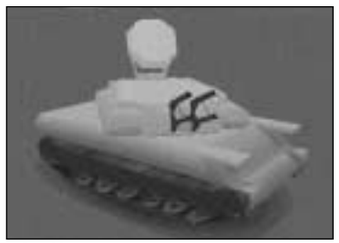

SA-6


SA-11


SA-17

Ground Vehicles


SS-23

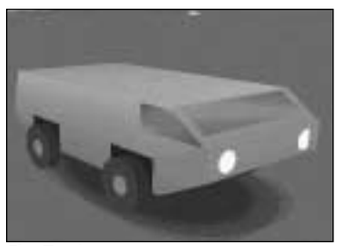

ZSU-23-4

Civilian/Supply Vehicles


Humvee

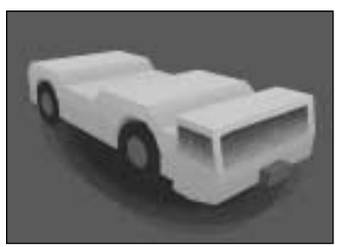

Bedford


Train


Fire Truck


Fuel Tanker


Truck


Tractor


Limousine

Ships

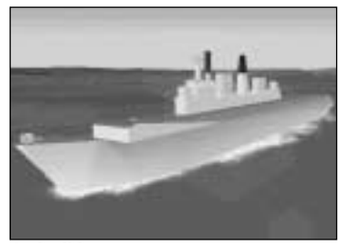

Anglo


Arleigh Burke

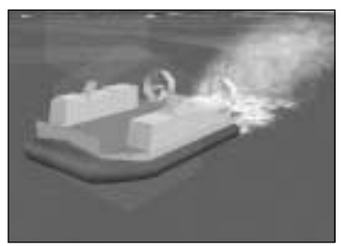

Avenger

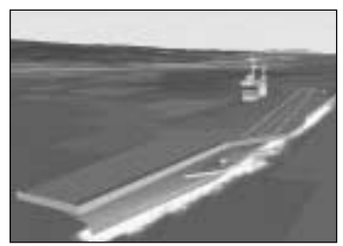

Charles De Gaul


Gepard


Invincible


La Fayette


L CAC

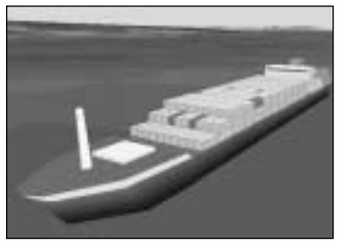

Nimitz


Oliver H Perry

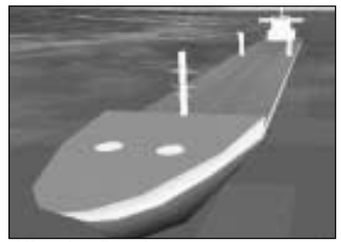

Type 23 Destroyer


Wasp

Ships (Civilian)


Container Ship


Dhow


Oil Tanker (large)


Oil Tanker (small)


Trawler


Ferry

Development of the F-22

Bill Sweetman

Air supremacy is the foundation of the US Air Forces doctrine and mission. The service believes that its first task is to ensure that it can control the skies in the theater of warfare, at any time and any place it chooses. This prevents hostile aircraft from interfering with air and ground operations or performing reconnaissance. Performed ably since the late 1970s by the McDonnell Douglas F-15 Eagle, this mission will pass in the next decade over to the Lockheed Martin F-22.

By the time the F-22 enters service in 2004, it will have been more than 20 years since the USAF formed an Advanced Tactical Fighter (ATF) program office to define the F-15s replacement. At the start of the 1980s, it was clear that Soviet planners had set out to meet the threat posed by new, agile US fighters in three ways. One was the development of new, fast, agile and heavily armed fighters: the MiG-29 and the larger, long-range Su-27. Almost more worrisome was the continued development of improved surface-to-air missiles. It also became apparent that the Soviet Union was working on airfield attack weapons.

Above: **Developed for air supremacy against all current and projected future threats, the F-22 will be one of the cornerstones of the USAF's Air Combat Command well into the future. Enhanced maneuverability , advanced avionics and stealthiness give the aircraft an edge in air-to-air combat.**

The F-22

Below: **The second YF-22A on an early flight. It was involved in a crash at Edwards AFB in April 1992, but was repaired for display at the USAF 50th Anniversary airshow at Nellis AFB in 1997.**

The USAF decided in 1982 that its first priority was to boost its force of low-level precision strike aircraft by modifying an existing fighter - a process which led to the F-15E Strike Eagle. The second step was to produce a new air-superiority fighter which would outclass the new Soviet fighters, as the F-15 and F-16 had outclassed the earlier MiG-23.

As the ATF requirement took shape, three S's stealth, supercruise and STOL - were the watchwords. Stealth would protect the aircraft from both fighters and SAMs, and give it the first-look, first-shot advantage in an engagement. (There were two problems, however; few people knew much about the jealously guarded secrets of Stealth, and not all of those who did were sure that it would work on a supersonic, agile fighter.)

Supercruise - the ability to fly at supersonic speeds without using afterburner - would give the ATF pilot the ability to choose whether or not to engage slower-moving threats. Short take-off and landing (STOL) would make it harder for an enemy to disrupt operations by cratering runways.

The Air Force wanted the ATF to have greater range than the F-15. This would allow it to operate from rear-area bases in Europe, and to intervene more effectively in theaters such as the Middle East, where mission distances are greater. With these very basic requirements in hand, the USAF was able to estimate the ATF's size and start development of the engines. (Having experienced growing pains with the F-15's engines, the USAF was determined to begin work on the ATF engines early.) In September 1983, Pratt & Whitney was awarded a contract for its XF119 and General Electric started work on the XF120.

Over the next two years, the USAF issued several draft ATF specifications, revising them in the light of industry reactions, and looked at ways to reduce the risk of technical surprises late in development. Eventually, the USAF decided to conduct an extensive demonstration and validation (Dem/Val) program with at least two competitors, in which the riskiest technologies would be tested at large scale.

The final request for proposals for the Dem/Val program was issued in September 1985. There were still seven fighter design teams in the US, and all of them responded: Boeing, General Dynamics, Grumman, Lockheed, McDonnell Douglas, Northrop and Rockwell.

Lockheed and Northrop had gone much farther than any of their rivals in blending stealth with supersonic speed and agility. This allowed the USAF to concentrate Dem/Val funds on two designs, making it possible to include flying prototypes in the program. Because it was clear that USAF money alone would not support a winning effort, and that contractors would have to invest heavily, five of the competitors formed teams: Boeing and Lockheed with GD, and Northrop with McDonnell Douglas. In October 1986, Lockheed's YF-22 and Northrop's YF-23 were announced as the eventual winners.

Dem/Val was the largest fighter competition in history, lasting more than four years and costing almost $2 billion. Each ATF team built two prototype aircraft. One of each pair of prototypes would have the P&W YF119, and the other would be powered by the GE YF120. The teams would build complete integrated avionics systems, and fly them on test-bed aircraft. They would test large-scale radar-cross-section (RCS) models and run thousands of wind-tunnel hours.

Above: **The exhaust nozzles on the first prototype YF-22 are the two-dimensional convergent-divergent type with vectored thrust to increase the pitch/turn rate and airfield performance.**

The competition did not start well for Lockheed, which had to discard its original swept-wing design in July 1987 when it turned out to be too heavy. Other changes followed as the USAF re-evaluated its requirements: the STOL specification was made less stringent to eliminate the overweight thrust reversers, and weight goals were changed.

When the YF-22 and YF-23 were unveiled, in the summer of 1990, it was clear that the two teams had driven in different directions. Northrop's clipped-diamond wing and V-tails showed that the emphasis was on stealth; Lockheed's vectoring nozzles and more conventional controls revealed a concern for low-speed agility.

Below: **The F-22 will be the first operational aircraft using thrust vectoring, giving the aircraft enhanced maneuverability at all speeds and allowing high angles of attack to be maintained.**

Lockheed/General Dynamics/Boeing YF-22A

Not since the F-104 has Lockheed built a fighter for the US Air Force, although its team member General Dynamics is among the world leaders with the F-16. In order to fully evaluate designs, the service ordered two prototype air vehicles of each design, one of each pair being powered by Pratt & Whitney engines, and the other by the General Electric Units. After choosing the YF-22 for the AFT requirement, the USAF stated the decision was finally based on the cost and a lower risk factor. While both engine and airframe competitions produced outstanding results, it was felt that the YF-22/F119 combination had the least chance of experiencing development problems, while also proving slightly cheaper than the other three.

Cockpit
The YF-22's cockpit is dominated by liquid-crystal colour displays which present the pilot with all relative information for flight. In the attack mode, salient information is presented in a sophisticated head-up display.

Radar
Giving first-look, first-launch, first-kill capability, the YF-22's radar has long range and high resolution for the early detection of opposing fighters. It has a low passive detection signature which, allied to the aircraft's own very low radar cross-section, allows the YF-22 to approach very close to its quarry before being detected, thereby dramatically increasing the chance of a kill.

Gun
Not fitted to the prototype air vehicles, an internal gun would be fitted to production machines. This may be the M61A1 20-mm Vulcan as carried by most USAF fighters, or an updated 25-mm calibre weapon.

Airbrake
Positioned between the fins is an airbrake which is controlled by the fly-by-wire system. The joints between the panel and the surrounding structure exhibit the classic sawtooth stealth shape.

Wing section
Although of large area, the YF-22's wing is very thin for good supersonic performance. YF-22's have demonstrated a supercruise (non-afterburning supersonic cruise) performance in excess of Mach 1.5.

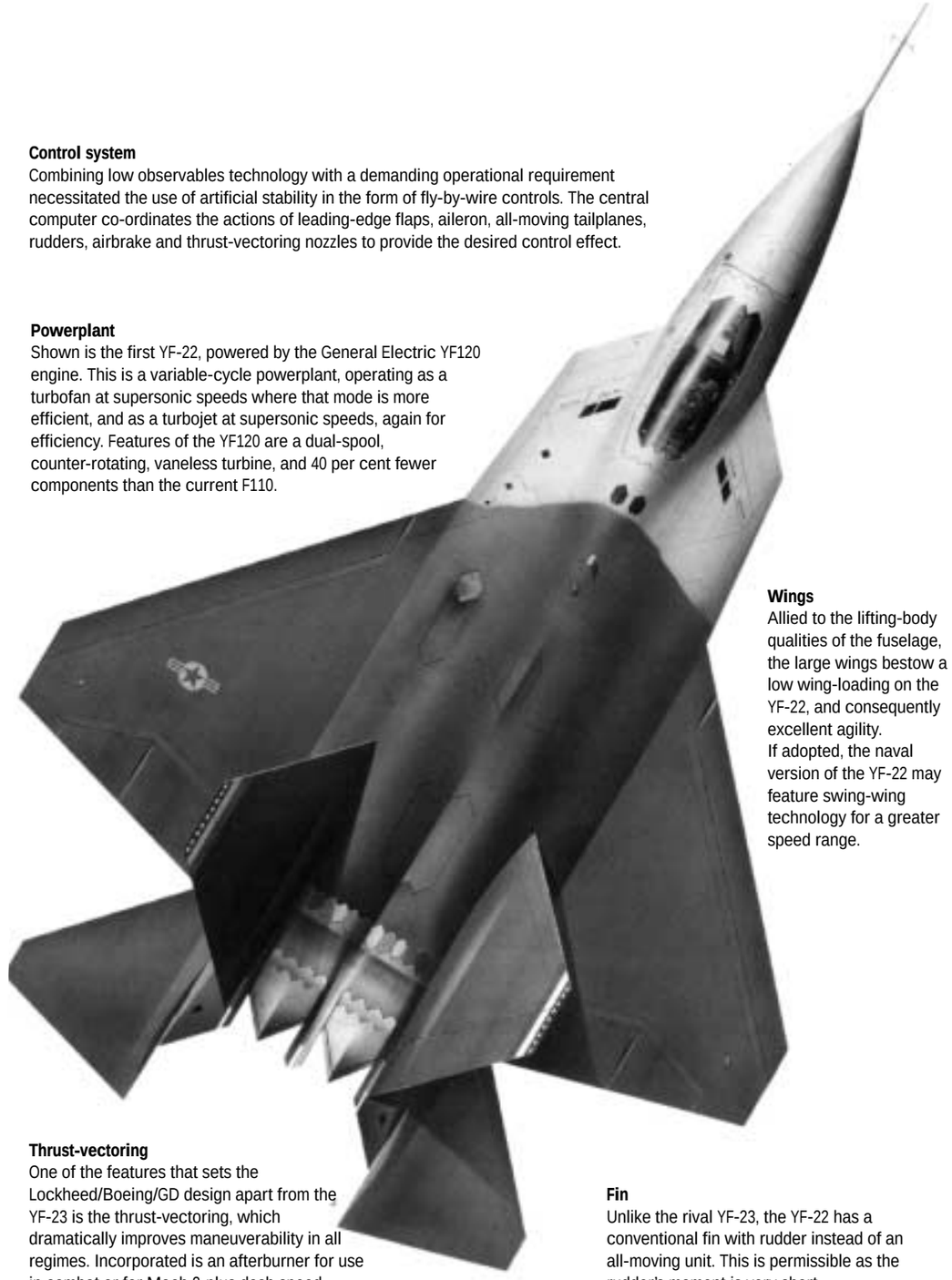
Intakes
The diamond-shaped intakes follow the same alignments in profile as the forward fuselage to preserve stealth characteristics. To shield the compressor faces from radar energy, the ducts form serpentine trunks leading upwards and inwards to the engine. A pronounced lip above the intake aids air ingestion at high angles of attack.

Missile bays
Missiles are carried in bays underneath and to the side of the engine intake ducts. On the sides are short bays for AIM-9 Sidewinder missiles, carried in pairs each side and ejected sideways, while longer bays underneath the intake hold four AIM-120 AMRAAM missiles, which fall away from the aircraft before the motors ignite.

Badges
This is PAV No. 1, and consequently carries the General Electric logo on the intake trunk. Other badges are Air Force Systems Command shield on the fin and small 'Skunk Works' badge on the base of the fin.

Control system
Combining low observables technology with a demanding operational requirement necessitated the use of artificial stability in the form of fly-by-wire controls. The central computer co-ordinates the actions of leading-edge flaps, aileron, all-moving tailplanes, rudders, airbrake and thrust-vectoring nozzles to provide the desired control effect.

Powerplant
Shown is the first YF-22, powered by the General Electric YF120 engine. This is a variable-cycle powerplant, operating as a turbofan at supersonic speeds where that mode is more efficient, and as a turbojet at supersonic speeds, again for efficiency. Features of the YF120 are a dual-spool, counter-rotating, vaneless turbine, and 40 per cent fewer components than the current F110.



Wings
Allied to the lifting-body qualities of the fuselage, the large wings bestow a low wing-loading on the YF-22, and consequently excellent agility.
If adopted, the naval version of the YF-22 may feature swing-wing technology for a greater speed range.

Thrust-vectoring
One of the features that sets the Lockheed/Boeing/GD design apart from the YF-23 is the thrust-vectoring, which dramatically improves maneuverability in all regimes. Incorporated is an afterburner for use in combat or for Mach 2-plus dash speed.

Fin
Unlike the rival YF-23, the YF-22 has a conventional fin with rudder instead of an all-moving unit. This is permissible as the rudder's moment is very short.

The F-22

Below: **With its in-flight refueling receptacle open (located half-way between the cockpit and the fins) the F119 powered YF-22 moves towards a tanker.**

Northrop was first in the air, on August 27, 1990; the first YF-22 flew on September 29, as soon as its YF120 engines were flight-qualified. Both teams flew their second aircraft in late October. A short, intense period of flight-testing followed - the two F-22s made 74 test flights in three months. In early November, the first YF-22 sustained Mach 1.58 without afterburner. During December, it demonstrated its spectacular low-speed maneuverability, performing 360˚ rolls at a 60˚ angle of attack.

Both aircraft met the key requirements, so the decision hinged not just on what the contractors promised in their proposals for engineering and manufacturing development (EMD), but on the customer's confidence in their ability to deliver. In early 1991, as the USAF evaluated the proposals, Northrop's partner, McDonnell Douglas, found itself embroiled in the collapse of the A-12 Avenger, while Lockheed's F-117 became the hero of the Gulf War. In several key areas, too, Lockheed had gone further in their demonstration program. The YF-22 alone had gone to high alpha; had fired missiles; and it had flown with a prototype advanced cockpit.

Together with the F-22's greater dogfighting potential, these considerations carried the day, and Lockheed was announced the winner of the EMD contract in April 1991. Pratt & Whitney's F119 engine was chosen as the ATF powerplant.

Since then, EMD has proceeded smoothly apart from some problems, now largely solved, with weight and radar cross section. The main cause of delays has been funding. Budget cuts have moved the first flight from August 1995 to May 1997, and have delayed initial operating capability from 2001 to 2004. Also, the Pentagon has reduced the planned F-22 fleet from 648 to 442 aircraft.

These actions have made the F-22 more expensive. The total F-22 program cost - development, 442 aircraft, spares, ground equipment and construction - stands at $73.5 billion in then-year dollars. Much of this total includes ten years or more of projected inflation. The projected average flyaway price of the F-22 is now $71 million in 1995 dollars. (Flyaway price includes a fully equipped aircraft but no spares or weapons.) Development cost is $11.5 billion in then-year dollars.

Nine single-seat F-22As and a pair of two-seat F-22Bs are being built for EMD. The first four F-22s will be used for structural, performance and handling tests, and the fourth will be the first two-seater. (An early ride in this aircraft awaits the F-22 team member who comes up with a name for the aircraft.) The fifth F-22 will have communications, navigation and identification (CNI) avionics on board. The seventh aircraft will have the Integrated EW System (INEWS), and the eighth F-22 will be the first with complete mission avionics; the fifth and sixth aircraft will be retrofitted with full avionics during the test program. The ninth and tenth F-22s will be used for integration and armament trials, and the 11th EMD aircraft will be configured for radar cross-section tests.

The big dollars are buying a fighter of deceptively conservative appearance. Its almost portly lines belie its speed and acceleration, and its size is not an indicator of its agility or detectability. Some of its internal features are as remarkable as its flight performance. The F-22's shape is dictated by the requirements of stealth, supersonic cruise and agility. Stealth demands that all weapons and fuel be carried internally, and influences the shape and angle of all external surfaces. Supersonic cruise requires low supersonic drag, which means a relatively high wing sweep and thin sections for the wing and tail surfaces. Enhanced agility is achieved through a large wing span and area and effective controls - these also give the aircraft improved STOL performance.

The F-22's stealth design evolved from the F-117. Both aircraft have a simple, monolithic shape, in contrast to the separate fore-

Above: **Both Dem/Val YF-22 aircraft pose for the camera in 1990. N22YF is powered by the General Electric YF120 while N22YX had the winning engine design, the Pratt & Whitney YF119. The YF119 was chosen soon after the F-22 was announced the winner of the ATF (Advanced Tactical Fighter) competition in April 1991.**

The F-22

body and nacelles of the YF-23. Surfaces and edges are aligned in groups: the wing and tail edges are parallel, as are the canted vertical tails and sloped body sides. Large openings such as the landing gear and weapon bay doors have serrated edges which follow the same primary alignments. Small apertures are diamond- or rhombus-shaped. The object is to ensure that the small residual reflections from edges and gaps are angled away from most radar that illuminate the aircraft.

Supercomputer-driven RCS prediction techniques have allowed the designers to incorporate curves in surfaces and edges and to use radar absorbent material (RAM) more sparingly. It is not applied over the entire aircraft, as on the F-117, but selectively to edges, cavities and surface discontinuities. New heat-resistant ceramic-matrix RAM is used on the exhaust nozzles, and better wide-band structural RAM is used on the wing edges. The radome is a bandpass type which reflects signals at all frequencies except the precise wavelengths used by the F-22 radar. A new low-RCS air-data sensor system, using four ports distributed around the forward fuselage. The F-22 is the first fighter to have a completely frameless canopy, eliminating the RCS contribution from the windshield arch.

The wing is a large-area clipped delta - efficient at high speeds, light in weight and with plenty of fuel volume. The wing is more sophisticated than it looks; large leading-edge flaps and complex camber make it more efficient at low speed and high alpha than earlier deltas.

The F-22 was designed to be able to reach extreme angles of attack while remaining under full control, and to recover safely from high alpha even without the help of thrust vectoring. The wing is located well aft, and the horizontal stabilizers are so close to it that the trailing-edge flaps are cut away to accommodate their leading edges. The surfaces work together for pitch and differentially for roll. When the nozzles are operating, they provide most of the pitch authority and the tails are primarily used to roll the aircraft.

Above: **Displaying the Pratt & Whitney badge on the engine air-intake and that of Air Combat Command on its tail, YF-22 number two sports a F-16-type two tone color scheme.**

Above: **Inflight refueling is an important part of the USAF's 'Global Reach/Global Power' doctrine, of rapid deployment of forces anywhere in the world. Here one of the prototypes engages a 'flying boom' of a tanker.**

The vertical tails are large, in order to provide stability and control at high alpha, when shorter surfaces would be masked by the wide forebody. In addition, the rudders can be deflected outboard in unison to serve as speedbrakes.

The heart of the F-22 structure is the mid-body section, built by Lockheed Martin Tactical Aircraft Systems in Fort Worth. (In 1994, Lockheed expanded its share of the F-22 program by acquiring General Dynamics tactical aircraft unit.) This section incorporates the four weapon bays, the main landing gears and the complex inlet ducts, which curve inwards and upwards from the inlets to mask the engine faces from radar. Attached to the mid-body are the forebody, accommodating the cockpit and avionics, which is built by Lockheed Martin in Marietta; the wings, aft fuselage and engine bay, and the tailbooms, built by Boeing. Lockheed Martin also builds the tail surfaces and radar-absorbent edges.

Five massive titanium bulkheads in the mid-body absorb most of the structural loads. The largest measures 16 feet between the wing attachment points and 6 feet from top to bottom, and starts life as the world's largest titanium forging, weighing 2975 kg

Above: **The F-22 has a power to weight ratio of more than one, which means it is able to accelerate in a vertical climb. The F-22's predecessor, the F-15 Eagle, was the first western aircraft to display this asset. Excess engine power also allows for weight growth in future versions of the aircraft.**

The F-22

(6560 lb). Some 95 per cent of its mass is removed during machining, leaving a 149 kg (329 lb) finished part. The F-22A uses more titanium and less composite material than the YF-22, mainly because titanium parts were less costly.

Without afterburning - which can be used for only minutes in any mission - it is 50 per cent faster than any fighter flying today. Acceleration and maneuverability, particularly at high speeds, have been shown to be excellent.

Above: **Both YF-22As flying over Edwards AFB. The red gantry on the nearest aircraft is a spin recovery parachute, fitted during the early trials 'just in case'.**

Most of the skin, however, consists of carbon fibers in a bismaleimide matrix material. Bismaleimides have displaced the epoxy matrix materials used in previous aircraft, because they can better withstand the high skin temperatures encountered at supersonic cruise speeds. Even so, the top speed requirement was reduced from Mach 2.0 to around Mach 1.8, to eliminate the need for more heat-tolerant thermoplastics.

On paper, the F-22 is slower than most of today's fighters. Maximum speed is set by airframe temperatures and by the use of fixed-geometry inlets - variable inlets are hard to make stealthy. But the F-22 will be able to attain its maximum speed with all weapons and most of its mission fuel, something which none of today's fighters can do.

One reason why such a large aircraft is so fast and agile is that the Pratt & Whitney F119-PW-100 is the most powerful fighter engine ever designed, with a maximum augmented thrust of 39,000 lb - giving the F-22 more power than two F-4s. Even so, maximum thrust does not tell the whole story. Because the F119 has a near-turbojet cycle, its military (non-afterburning) rating is a larger percentage of its maximum power than is the case for the previous generation of engines. Also, it can withstand much higher turbine temperatures, so it does not need to be throttled back as much at high speeds. At Mach 1.4, on dry thrust, the F119 generates twice as much power as the F100-PW-200.

Despite its greater thrust, the F119 has 40 per cent fewer parts than the F100. New computer-aided aerodynamic design techniques have made it possible to design thicker, more highly loaded compressor and turbine blades and achieve more compression in fewer stages. The F119 has a three-stage fan, a six-stage compressor and single-stage low- and high-pressure turbines. It has counter-rotating shafts: this makes the engine lighter, shorter and increases efficiency.

The F-22 is armed with six AIM-120C Advanced Medium-Range Air-to-Air Missiles (AMRAAMs) in the ventral bays. Weapons were a controversial issue. Ideally, a fighter with internal missile bays should have a compact missile with folding fins; but this would mean that the F-22 would not be able to carry standard

Below: **The unusual layout of the rear of the YF-22 is seen here to good advantage. The angle of the leading edge of the wing and the horizontal tail are both set at 48 degrees on the YF-22 and 42 degrees on the F-22A.**

Throughout the fan and compressor, the disks and blades are one-piece components. The large, hollow-titanium first-stage blades are made separately and joined to the disk by linear friction welding, a technique in which the blade is rubbed so hard against the disk that it bonds to it. The two-dimensional vectoring nozzles can divert the full augmented thrust 20° upwards or downwards in a fraction of a second, and provide the aircraft with the required stealth characteristics when it is viewed from the rear.

missiles, while folding fins might not be able to withstand the stresses of external carriage on other fighters. The AIM-120C is a compromise: with shorter wings and tails than earlier AMRAAMs, it fits better in an internal bay, but its performance is virtually identical and it will become the standard version for all USAF fighters. The AIM-120s will be propelled from the weapon bays by pneumatic/hydraulic ejectors.

The F-22

Initially, the side bays will each hold one AIM-9 Sidewinder missile. However, the future AIM-9X will have small tail surfaces rather than the large wings of the current AIM-9, and it is likely that the F-22 will be able to carry two of these per side. The AIM-9s will be launched from a trapeze-mounted rail which will be extended before the missile is fired, allowing the infra-red seeker to lock on before launch.

For operations where stealth is not critical, the F-22 can carry up to 2270 kg (5,000 lb) of external stores on each of four underwing pylons. These can each accommodate a 600 US gal. fuel tank, significantly increasing its range and endurance.

Above: **One of the concessions to steathiness is that the fins are set at the same angle as the fuselage sides. This helps to produce fewer 'spikes' on radar when the aircraft is viewed from many angles, as all reflected radar energy is directed away from the radar source. If the aircraft turns so that the energy is directed to the radar, the sudden increase in returns makes it look like a 'gliche' in the radar system.**

A Lockheed Martin M61A2 cannon, a lighter-weight version of the veteran M61 with longer, composite-wound barrels, is mounted above the right wing root. An inward-opening door covers the muzzle to preserve the fighters stealth qualities.

The USAF asked Lockheed in 1994 to develop an air-to-surface capability for the F-22. The lower weapon bays have been modified to accommodate a single 1,000 lb GBU-30 Joint Direct Attack Munition (JDAM) per side. The GBU-30 is guided by a simple GPS/inertial system, but later versions will have a programmable radar seeker for precision attacks. A synthetic aperture radar (SAR) mode is being added to the F-22's radar for air-to-surface operations.

The F-22 is new in so many ways that conventional sensors and displays would be inadequate. The air battle will unfold more quickly in front of the F-22 pilot, because of the fighter's greater speed. The F-22 relies on its stealth for protection against hostile air defenses, but stealth can be compromised by emissions from its own systems. Stealth gives the pilot a new set of variables to consider; the F-22 is more stealthy against some radar than others, and its radar reflectivity varies according to the radar's bearing.

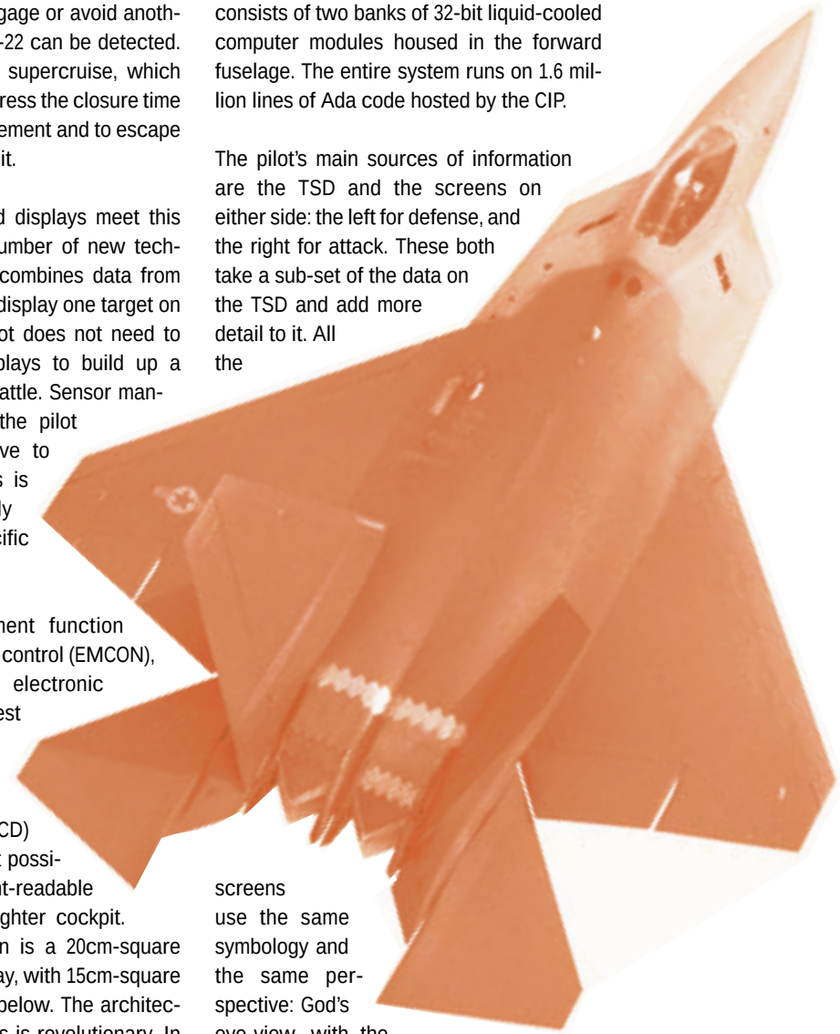
Stealth gives the F-22 the initiative in a beyond-visual-range (BVR) engagement, allowing the pilot to engage or avoid another aircraft before the F-22 can be detected. It is complemented by supercruise, which allows the pilot to compress the closure time at the start of an engagement and to escape and avoid at the end of it.

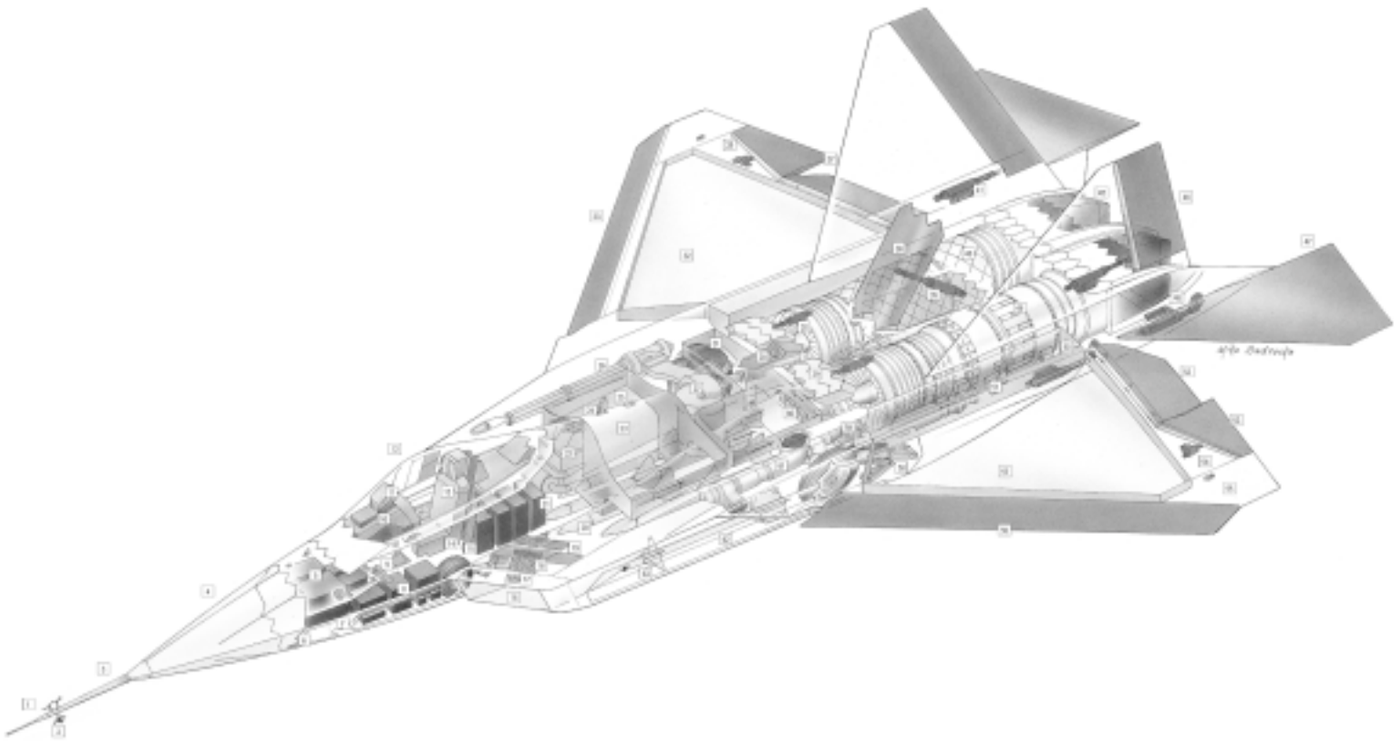
The F-22's sensors and displays meet this challenge through a number of new techniques. Sensor fusion combines data from all different sensors to display one target on the screen, so that pilot does not need to compare different displays to build up a mental picture of the battle. Sensor management means that the pilot does not normally have to control the radar. This is done automatically according to the specific tactical situation.

The sensor management function also performs emission control (EMCON), automatically, keeping electronic emissions at the lowest possible level.

Active-matrix liquid crystal display (AMLCD) technology has made it possible to fit large, sunlight-readable colour displays in a fighter cockpit. The centre of attention is a 20cm-square Tactical Situation Display, with 15cm-square screens left, right and below. The architecture behind the displays is revolutionary. In today's fighters, the radar, electronic combat (EC) system, and communications, navigation and identification (CNI) systems are separate, and each has its own processors. The F-22 sensors are not independent systems, but together with the displays are peripherals serving the fighter's GM-Hughes Common Integrated Processor (CIP), which consists of two banks of 32-bit liquid-cooled computer modules housed in the forward fuselage. The entire system runs on 1.6 million lines of Ada code hosted by the CIP.

The pilot's main sources of information are the TSD and the screens on either side: the left for defense, and the right for attack. These both take a sub-set of the data on the TSD and add more detail to it. All the screens use the same symbology and the same perspective: God's eye-view, with the F-22's track pointing up the centre of the screen. The symbols are "dual-coded" - as far as possible, they differ both in shape and color. This makes them easy to distinguish and ensures that the displays will be workable even in brilliant sunlight or if the pilot has to wear laser-protective goggles (during night time operations).





Lockheed/General Dynamics/Boeing YF-22A

1 Pitot head
2 Yaw and pitch vanes
3 Test instrumentation boom
4 Radome (radar not fitted to prototype aircraft)
5 Radar equipment module
6 Pitot head
7 Flush air data sensors
8 Avionics equipment bay
9 Rudder pedals and control column (fly-by-wire control system)
10 Instrument panel shroud (multi-function head-down-displays)
11 Head-up displays
12 Upward-hinging cockpit canopy cover
13 Pilot's ejection seat
14 Canopy hydraulic actuator
15 Nosewheel stowage
16 Fixed geometry pitot-type intake
17 Internal boundary layer suction air grille
18 Flow control panels/spoilers
19 Boundary layer spill air louvers
20 AIM-120 AMRAAM missiles (four) in ventral bay
21 Avionics equipment
22 Air conditioning pack
23 Forward fuselage fuel tank
24 Communications aerial
25 Strobe light
26 M61 Vulcan cannon installation (not fitted to prototype aircraft)
27 Ammunition magazine
28 Flight refueling receptacle
29 Intake suction relief doors
30 Suction relief door hydraulic actuator
31 Starboard mainwheel stowage
32 Starboard wing integral fuel tank
33 Leading edge flap
34 Starboard navigation light
35 Aileron hydraulic actuator
36 Starboard aileron
37 Starboard plain flap
38 Airbrake panel
39 Airbrake hydraulic actuator
40 Pratt & Whitney F119 afterburning turbofan engine
41 Rudder hydraulic actuator
42 Starboard fin
43 Rudder panel
44 Starboard all-moving tailplane
45 Variable area and thrust vectoring afterburner nozzle flap
46 Port rudder
47 Port all-moving tailplane
48 Tailplane hydraulic actuator
49 General Electric F120 afterburning turbofan alternative engine installation
50 Fuselage flank fuel tank
51 Flap hydraulic actuator
52 Port plain flap
53 Port aileron
54 Aileron hydraulic actuator
55 Port navigation light
56 Leading edge flap
57 Port wing integral fuel tank
58 Port mainwheel stowage
59 Mainwheel hydraulic retraction jack
60 Airframe mounted accessory equipment gearbox
61 Auxiliary power unit (APU)
62 Fuselage flank missile bay
63 AIM-9L Sidewinder air-to-air missile

The F-22

Above: **Flown for the first time on the 7th of September 1997, F-22A 91-001is the first Raptor to display the production configuration, with the exception of the probe on the nose**

SPECIFICATION

Lockheed/Boeing F-22A

Wing: span 44 ft 6 in (13.56 m); aspect ratio about 2.36; area about 840.00 sq ft (78.04 m2)
Fuselage and tail: length 62 ft 1 in (18,92 m); height 16 ft 5 in (5.00 m)
Powerplant: two Pratt & Whitney F119-P-100 each rated at 35,000 lb st (155.69 kN) with afterburning
Weights: empty more than 30,000 lb (13608 kg); maximum take-off 58,000 lb (26308 kg)
Speed: maximum level speed 'clean' at optimum altitude Mach 1.58 in supercruise mode and at 30,000 ft (9145 m) Mach 1.7 in afterburning mode
Performance: service ceiling 50,000 ft (15240 m)
g limits: +7.9

The F-22's sensor management and EMCON functions automatically control the sensors and communication systems in order to detect and track targets and co-ordinate attacks without betraying the fighters presence. The most important sensors are the Westinghouse /Texas Instruments APG-77 radar and the passive electronic surveillance measures (ESM) incorporated into the Lockheed /Sanders electronic combat system.

The APG-77 has an active electronically steered antenna (AESA), which consists of well over 1,000 finger-sized transmit and receive modules embedded in a fixed array. The cost of these modules has been the critical issue in the radar's design. In the EMD radar, a pair of transmit and receive modules weighs a mere 15g and puts out over 4W of power. The aim is to bring the cost down to a point where any flawed modules can be discarded and easily replaced.

The APG-77 is expected to be extremely agile, capable of changing the direction, power and shape of the radar beam very rapidly to acquire target data while minimizing the chance that its signals will be intercepted or tracked. It should also be reliable: many radar failures today are caused by transmitter or power supply problems, which are largely eliminated by the modular design and construction of the APG-77 antenna and power section.

The F-22's ESM system is vastly superior in sensitivity and precision to any current fighter system. With large conformal antennas in the wingtips and outer leading edges, it can determine the target's bearing and, to some extent, its range.

The fighter also incorporates a sophisticated datalink which can import target information from AWACS aircraft behind the battle area. The fighter also has a low-probability-of-detection short-range datalink which can transfer system and target information among F-22s so that all the pilots in a flight can see the same displays.

The sensor management and EMCON functions divide the airspace around the F-22 into concentric zones. In the outer zone, targets are not close enough to be a threat, and the system will not break radar silence to identify them. As they get closer and enter the "situational awareness" zone, the system is programmed to identify and track them, whilst remaining stealthy.

Above: **Only 83 years passed between the Wright Brothers' first controlled flight and that of the YF-22s. One can only wonder what the brothers would have made of the aircraft.**

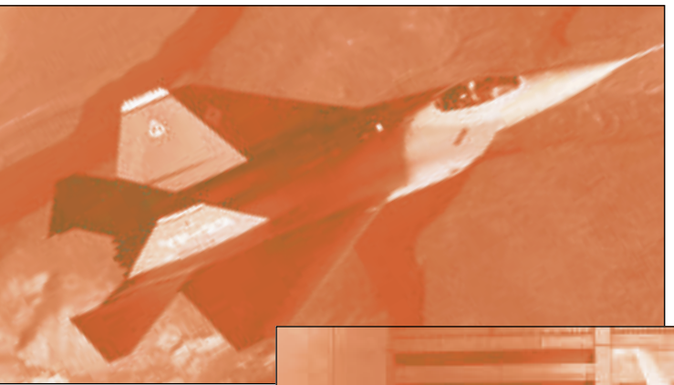
The next zone is defined as that within which the F-22 pilot has the option to engage or avoid the threat. The inmost zone is bounded by the range of the threat's missiles. In each case, the system uses the radar only as much as is necessary to maintain a track. As the target gets closer, the radar will revisit it more often.

As targets are detected - whether by AWACS, the F-22's radar or by ESM - the F-22's software assigns them to a track file. As other sensors pick them up, the information is placed in the same track file, and the best data is drawn from the file and displayed. For instance, the display will show range and speed information acquired by the APG-77 and bearing data from the ESM.

Below: **F-22 Chief Test Pilot, A. Paul Metz, is a former Northrop test pilot and graduate of the Air Force Test Pilot School, having flown more than 72 types of aircraft in a 33 year career. He made the first flight in the rival Advanced Tactical Fighter, the Northrop YF-23A, in August 1990, prior to joining Lockheed Martin Aeronautical Systems**

The CIP will identify the hostiles and computes the detection envelope of the hostile's radar and missiles against the F-22 at its cur-

The F-22



Above: **The Number Two YF-22 differs from the Number One aircraft in engines and other subtle ways. Compared to the Number One aircraft (on the opposite page) the dark paint scheme does not come as close to the cockpit.**

Right: **First EMD F-22A. The official name chosen for the F-22 was 'Raptor'. Derived from the Latin word meaning 'to seize and carry off', raptors are usually large, strong birds, with hooked beaks and sharp talons for grasping and killing prey.**

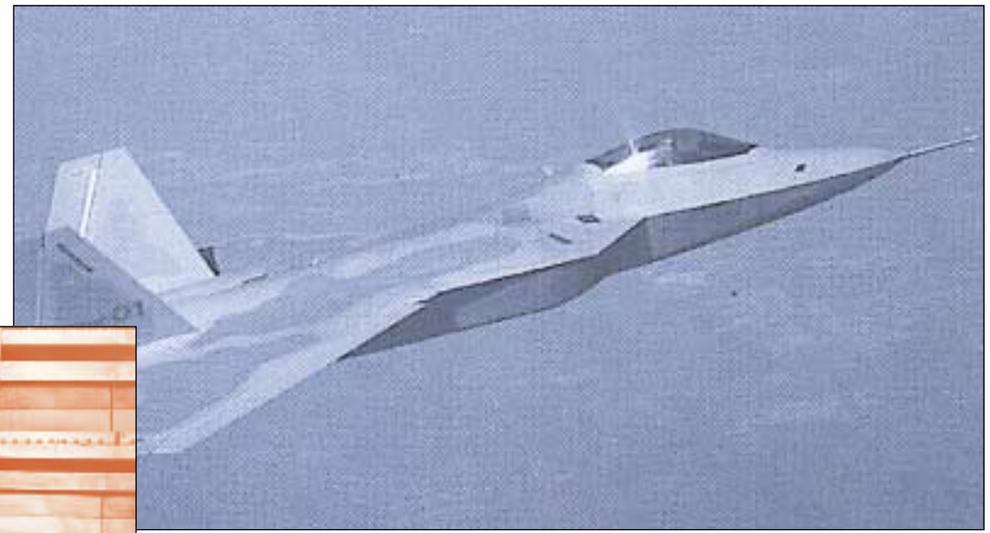
rent bearing. The CIP will do the same for any SAM radar.

The computers also help the pilot by assembling a "shoot list": the targets are placed in order of priority and tracked for engagement. The attack display shows the maximum range of the F-22's own missiles - corrected for launch speed and altitude - and the lethal envelope of the target's missiles. The shoot-list function selects and arms missiles automatically.

The F-22 pilot can see when the target will be within range, and when to break off, and can use that information to decide whether to fire as soon as possible - and break away earlier - or whether to allow the range to close and give the target less chance to escape. Simulations have shown that the F-22 can often put AMRAAMs within no-escape range of the target before the target can even detect its attacker.

A helmet-mounted display (HMD) was not part of the F-22 baseline, but HMD technology is being developed under a separate joint-service program. A qualified HMD should be available by the time the F-22 enters service.

Despite its remarkable capabilities, the F-22 should not be a hard-to-maintain, exotic aircraft. From the outset, one of the main program goals has been to produce an aircraft that requires fewer maintenance people and



Left: **The first Engineering and Manufacturing Development (EMD) F-22A Raptor is painted in a 'Mod Eagle' type color scheme, with a low visibility Air Combat Command shield displayed on the top of the fins, denoting its future operator.**

a smaller logistics train than the F-15. Every part of the F-22 has been designed by an integrated product team that includes engineers and specialists in production and maintenance. The avionics system is designed around modules that can be removed and replaced without tools. Any external maintenance on the F119 can be carried out with a set of box wrenches, ratchets and sockets. With fewer parts and more built-in test equipment, a 24-aircraft unit of F-22s requires only eight C-141B-loads of equipment for a 30-day deployment, versus 18 for the same number of F-15s.

Familiarity can breed contempt. The ATF has

Below: **The first EMD F-22A is rolled out from the production facility for the first time. The re-profiled nose contours are very evident in this shot. Many subtle differences have been incorporated into the F-22A**

Above **Named 'Spirit of America', the first EMD F-22A is unveiled to the world at an elaborately staged roll-out on 9th April 1997. With modern major combat aircraft costing vast amounts to design and produce the unveiling ceremonies are seen as a way to drum up continuing support for dwindling 'tax dollars'.**

been around for a long time, and it is seldom appreciated that its entry into service - even in 2004 - will be the biggest advance in fighter capability in history. The F-22 heralds the greatest increase in sustained speed since the advent of the jet. It takes the energy maneuverability of the F-16 and extends it into the supersonic realm. It brings the potential of all-aspect stealth to bear on air combat, and couples it with advanced avionics which bring about an unprecedented improvement in the pilot's situational awareness. If it lives up to its potential, it will be the undisputed ruler of the skies for most of the first half of the 21st century.

Sukhoi Su-35 'Flanker'

Jon Lake

The Su-27 was designed during the 1970s as a replacement for the Su-15 and MiG-25 with the fighter element of the Soviet Union's air defense forces - the IA-PVO. Large numbers subsequently entered service with Frontal Aviation as long range escort fighters. The baseline 'Flanker' had no appreciable air-to-ground capability, but combined very long range and very high combat persistence with remarkable agility (especially at low weights). Entering service in the mid-1980s the Su-27 was initially compared to Western aircraft like the McDonnell Douglas F-15, although it was more agile, with longer range, and considerably less versatility and overall capability. The Su-27 used a very similar aerodynamic configuration to the smaller MiG-29, and in some respects can be regarded as a larger, longer-ranged equivalent, sharing many of the Fulcrum's characteristics, strengths, and weaknesses. The two Russian aircraft even shared related IRST equipment, RHAWS and different models of the same N-019 'Slot Back' radar.

Twin engines conferred a high degree of safety and survivability on the Su-27, while also allowing a very high thrust-to-weight ratio. This in turn allowed the Su-27 to enjoy superb outright performance characteristics. The high lift, low-drag wing gave good turn performance, while the clever aerodynamic design gave unmatched high *a*, and slow speed capability. Unlike the MiG-29, the Su-27 did have a fly by wire flight control system (albeit with a conventional mechanical rudder control system and analog and not digital signalling for the pitch and roll channels, unlike the latest Western fighter types). This did have similar 'soft' limits which could be overridden, giving the pilot the ability to exceed normal limits when necessary, while running an increased risk of departing from controlled flight (most likely in a dogfight).

Above: **Seen displayed in the wet at Farnborough is a pre-production prototype Sukhoi Su-35. The Su-35 differs from the earlier Su-27 'Flanker' in a number of important aspects, having radar, flight control system and airframe improvements.**

Sukhoi Su-35

America briefly fielded a semi-experimental helmet-mounted target designator on a handful of late-model US Navy and Marine Corps F-4 Phantoms, but it was left to nations like Israel, South Africa and the USSR to field the first practical helmet sights operationally. The helmet sight used by MiG-29 and Su-27 pilots is extremely simple, and above all light, with a single eyepiece through which the pilot looks at his target, and with head position sensors calculating exactly where his head is pointing in order to cue the IRST or missile seeker heads. The sight's designers resisted the temptation to add the weight and complexity of night vision aids, displays, or eye position sensors, producing instead a simple but effective way of pointing the IRST or missile seeker where the pilot pointed his head.

The helmet sight is augmented by an excellent short-range missile armament consisting of up to four Vympel R-73 (AA-11 Archer) IR-homing missiles. The basic R-73 missile has a seeker Field of View of about 30˚ or 45˚, and can be slaved to the radar, the IRST, or the pilot's helmet mounted sight. This allows the Su-27 pilot to engage a target well off his axis, far from his boresight. Off boresight capability is not as great as has been claimed in some sources (one Western author claims 105˚ each side of the centerline), but with R-73 and helmet sight together, probably represents a slice of sky out to between 45 and 60˚ off the nose, laterally and in elevation. The R-73 has agility to match its wide seeker limits, with a vectoring rocket motor nozzle, trailing-edge flaperons on the rear fins and moving forward control fins. These features allow the missile to make an extremely hard turn off the pylon for extreme off-boresight shots (although this naturally bleeds away energy and finite pneumatic control power, dramatically reducing maximum range). Despite its large size, the Su-27 has a relatively low frontal RCS, and can accelerate very rapidly indeed. This, combined with the reach of its R-27RE (extended range AA-10 Alamo) AAMs, make it a formidable BVR opponent, as well as a deadly foe in close combat.

The Su-27 is rather more expensive than the baseline MiG-29, but still represents a cheap fighter by international standards, and like the MiG, is well-equipped, with data link, RHAWS, and a comprehensive defensive ECM system. The aircraft is also capable of operating from relatively primitive forward airstrips. Although it was never exported in the same numbers as the smaller MiG-29, the Su-27 was sold to China and Vietnam, and was transferred to the air forces of Belarus, Ukraine and Kazakhstan after the break-up of the USSR. The type continues to be aggressively marketed, and can be expected to be encountered almost anywhere. The Su-27 is highly maintainable and repairable and is very resistant to battle damage. The aircraft uses pneumatic systems instead of more flammable hydraulic systems wherever possible, and fuel tanks are well protected with self-sealing surfaces and reticulated foam linings. In USAF simulations during the mid 1990s, it was reportedly discovered that the very widely spaced engines of the Su-27 made it necessary to fire two AMRAAMs to be absolutely sure of ensuring a kill against the Flanker or Fulcrum. Although the use of smart algorithms to direct the missile against the cockpit area rather than the engines or center fuselage have increased missile lethality, the Su-27 remains extremely tolerant to damage.

Unlike the MiG-29, the Su-27 has very high combat persistence, with no less than ten AAM stations which can carry six BVR and four IR-homing missiles. The last production Su-27s had two extra underwing pylons, bringing the total to twelve and compensating for the potential loss of the wingtip pylons when the optional Sorbitsiya ECM pods were fitted. The Su-27 is as well-endowed with defensive expendables as it is with hardpoints for weapons. Chaff/flare dispensers are buried in the tailcone, and in fairings flanking the tailcone, with a total of up to 96 cartridges. The aircraft, when fully fuelled, has a very long unrefueled radius of action, and can stay on CAP for extended periods. This allowed the aircraft to perform as a long range air defense aircraft or as an escort fighter, although its agility was much reduced at high all up weights.

Just as it shared many of the strengths of the MiG-29, so the Su-27 shared many of the weaknesses of its smaller cousin, as well as having some unique disadvantages. The Su-27's large wing planform makes it very easy to see from some angles, rather like the F-15. Like the MiG-29, the Su-27 suffers from poor integration of systems and avionics, imposing a high cockpit workload and forcing the pilot to place an undue reliance on external agencies (GCI or AWACS) for threat and target prioritization. Like the MiG-29, the Su-27 is not easy to fly, and its systems are difficult to manage, demanding constant attention, and reducing the pilot's capacity to maintain situational awareness.

Like the MiG-29's RD-33 turbofans, the Su-27's AL-31s suffer from short time between overhaul figures, and can be smoky using certain fuels. Like the MiG-29, the Su-27 relies on the relatively poor R-27 (AA-10 Alamo) missile as its primary BVR armament, but the inadequacies of this missile are partially offset by the large number of missiles carried. Like the MiG-29, the Su-27 carries little ammunition for its internal cannon, and like the MiG-29 has no appreciable precision attack capability.

The shortcomings of the basic Flanker were addressed in the Su-27M (later known as the Su-35) which was designed to replace the earlier aircraft, while improving on its rather limited multi-role capability. Secondary aims of the Su-27M program were to further increase agility and to improve air-to-air performance by integrating new weapons and a new, more effective multi-mode radar. When European nations began developing their advanced fighters (Eurofighter, Rafale and Gripen) they took the Su-35 as their baseline threat aircraft, factoring in further development, and assuming radar and missiles equal to the best the West would have to offer in the time scale envisaged. Although Su-35 development was retarded by financial problems, the aircraft probably finished up more capable and more deadly even than European aircraft companies and defense ministries had feared. The aircraft was certainly more capable in the ground attack role, and probably had better AAMs and radar, and was certainly considerably more agile than had been assumed.

The Su-27M was made between three and five times more unstable than the basic Su-27, and new all-moving canard foreplanes were added to the LERXes. This necessitated the adoption of a new quadruplex digital FBW flight control system, and allowed the a limit to be raised to 30 units. Agility was further enhanced by the adoption of more powerful AL-31FM (AL-35F) engines. It is believed that current production Su-35s incorporate a sidestick controller in place of the conventional central control column.

The maneuvrability and STOL characteris-

Sukhoi Su-35

Above: **Head on view of a Su-35. This aircraft carries AAMs outboard and ASMs inboard and under the nacelles. Streamline ECM pods are carried on the wingtips of this aircraft, but AAMs can be carried on rails on the tips. The aircraft was designed as an interceptor but it can carry a significant air-to-ground payload.**

tics of the Su-35 can be further enhanced by the addition of thrust vectoring engine nozzles, test flown on an Su-35 prototype and now available for retrofit or as an option for new customers.

The close proximity of the tailplanes and central tailsting to the engine nozzles effectively limits them to two-dimensional (up-down) movement, but this is invaluable for improving high *a* performance, increasing pitch rates, and improving take off and landing distances.

While the dynamic deceleration maneuvres demonstrated by the Su-35 at countless airshows cause a dramatic loss of energy, they are far from being mere 'circus stunts'. They allow the Su-35 pilot to bring his sights to bear for a snap missile shot, and could be invaluable in a slow turning fight or scissoring engagement. At beyond visual range, the dynamic decelerations could cause the Su-35 to briefly disappear from a pulse Doppler radar display, or to break a radar lock.

The Su-35 was designed around basically the same multi-role avionics system as the MiG-29M, albeit with a larger, more powerful version of the same basic multi-role radar, and with the addition of a rearward-looking N-012 radar in the tailcone. The new radar has a longer range (about 400 km or 250 miles for a fighter-sized target) and can simultaneously track up to 15 targets, and engage six of them. It is probable that many Su-35s in service today have Zhuk PH radar, with a modern phased array antenna. This has a slightly reduced detection range, but offers wider scan limits and allows the simultaneous tracking of up to 24 targets.

For the air-to-ground role, the radar was capable of performing various types of mapping and ranging functions, as well as terrain following and terrain avoidance. The radar was backed up by a redesigned electro-optical complex, which incorporated a laser designator and TV camera for the first time. This allowed the new version to use a range of new laser and TV guided bombs and missiles. Although it has a formidable air-to-ground capability, the Su-35 remains primarily an air superiority aircraft. In the air-to-air role, the aircraft can carry the semi-active radar homing R-27 (AA-10 Alamo), the active radar R-77 (AA-12 Adder) and the short-range IR-homing R-73 (AA-11 Archer), very much like the MiG-29M. With fourteen external hardpoints (and with no need for external fuel), the aircraft has considerable combat persistence. Most impressively the aircraft can carry the ultra-long range Novator KS-172 AAM-L or the R-37 usually associated with the MiG-31M.

The Su-35 was also given a more modern glass cockpit, with some four monochrome CRT displays, two on the panel, and two on the side consoles. These replaced the old radar display and some analog instruments, though conventional analog *g* and *a* meter, artificial horizon, compass ASI and altimeter were retained in the center of the panel. Moreover, the new displays themselves were rather old-fashioned, monochrome CRTs rather than modern high-brightness color LCDs, and with twenty input buttons clustered around each. Moreover, they are located well down in the cockpit, far from the pilot's eyeline. They represent only a minor improvement over the all-analog cockpit of the basic Flanker. It is believed that color LCD displays were flown in at least one Su-35 prototype, but as far as can be ascertained, have not yet been integrated in production aircraft.

Surprisingly, in view of the very high fuel capacity of the basic Su-27, fuel tankage has been further increased (by about 1500 kg/3,000 lb) in the Su-35, and a retractable inflight refueling probe is mounted below the port side of the windscreen. This leaves the Su-35 with an incredibly long range, and the potential for extended CAP loiter times. Unless you have just come off the tanker and have caught an Su-35 close to his 'bingo' fuel, trying to run him out of fuel will not be a successful tactic.

At air combat ranges, the naval version of the Su-33 is all but identical to the Su-35 in appearance, though it is a canard-equipped naval derivative of the basic Flanker-B, with the original flight control system and the original Slot Back radar, with all that this infers for combat capability. The Su-30 is a two-seat interceptor based on the original Su-27UB, with Slot Back radar and with no canard foreplanes, while the Su-30M is similar, but with a limited measure of multi-role capability. These Slot Back equipped versions should not be underestimated, since the radar has undergone a series of modifications and improvements to give better multiple target capability and since the aircraft remains an agile and deadly foe. The Su-30, in particular, has the advantage of a second crew member, who can reduce the handling pilot's workload, and who can enhance the overall crew situational awareness. The Su-30 may also function as a mini-AWACS, controlling groups of fighters, usually standard Su-27s, Su-35s or other Su-30s. Upgrades and improvements may have given these types compatibility with many of the air-to-air weapons used by the Su-35. Both the Su-33 and the Su-30 are equipped with retractable inflight refueling probe, offering the possibility of even longer

SPECIFICATION

Sukoi Su-35

Wing: span 15.16 m (49 ft 8.75 in) over ESM pods; aspect ratio 5.6; wing area 46.50 M2 (500.54 sq ft)

Fuselage and tail: length 22.183 m (72 ft 9 in); height 6.84 m (22 ft 5 in); tailplane span 9.90 m (32 ft 6 in); wheel track 4.33 m (14 ft 2.5 in); wheel base 5.88 m (19 ft 3.5 in)

Powerplant: two NPO Saturn (Lyul'ka) AL-31FM turbofans, each rated at 130.42 kN (29,321 lb st) with afterburning

Weights: empty (40,564 lb); normal take-off 26000 kg (57,319 lb); maximum take-off 34000 kg (74,956 lb)

Load: maximum external load 8000 kg (17,637 lb)

Speed: maximum level speed 'clean' at 11000 m (36,089 ft) 2500 km/h (1,349 kt; 1,553 mph), and at sea level 1400 km/h (756 kt; 870 mph)

Range: at high-altitude with four AAMs 3500 km (1,889 nm; 2,175 miles); range at low-altitude with four AAMs 1450 km/h (783 nm; 901 miles); ferry range 4200 km (2,267 nm; 2610 miles); range with inflight refueling in excess of 6800 km (3,670 nm; 4,225 miles)

Performance: maximum rate of climb at sea level 19800 m (64,960 ft) per minute; service ceiling 17700 m (58,071 ft); take-off run 450 m (1,476 ft) at maximum take-off weight; landing run 700 m (2,297 ft) at normal landing weight.

Sukhoi Su-35

Above: **The infra-red search and tracking sensor is mounted in front of the cockpit, allowing the aircraft to find targets without switching on its Fazotron N011 Zhuk 27 radar. The new square-tip fins containing fuel can be compared with those of the Sukhoi 'Flanker' in the background which has the 'cut-off' fin tops.**

range and greater endurance.

Further Su-27, -33 and -35 upgrades could bring these aircraft up to almost the same standard as an Su-35. The new Zhuk radar can easily be retrofitted, and even canards and the new flight control system could be installed in existing Su-27 airframes. Although the Su-35 airframe did incorporate more use of composite materials and welded aluminum-lithium alloys these were not crucial to the enhanced capability and performance of the new variant. Thus an upgraded Su-27 could be almost as capable as a new-build Su-35, and unless you can be confident in the accuracy of your intelligence sources you should assume that any Flanker encountered is as capable as the thrust vectored Su-35.

All current Flanker fighter variants can carry anti-radar missiles, and can function as long range defense suppression aircraft. More significantly, the supersonic, passive radar homing, long range Kh-31P can be used as an air-to-air anti-radar missile, especially against vulnerable allied aircraft like the E-3 Sentry AWACS platform or the E-8 J-STARS. Russian tactical doctrine emphasizes the importance of such aircraft as targets, and the best and most experienced pilots are trained in co-ordinated attacks against such aircraft and their HVACAP (High Value Asset CAP) fighter protection.

Another aircraft similar in appearance to the Su-35 is the Su-34 strike aircraft (and the dedicated anti-ship Su-32FN) which is understood to use the same digital FBW control system as the Su-35 and which has an advanced attack radar. This aircraft would normally be expected to be encountered at high weights, and carrying air-to-surface weapons, and is unlikely to present more of a threat than a basic Flanker-B. The Su-34 and Su-32FN can however carry a nasty surprise, in the shape of a rearward facing R-73 (AA-11 Archer) missile. In conjunction with a rearward-facing radar in the tailcone, this makes the aircraft's six far from vulnerable and unprotected from close ranges. Approach with caution!

The disintegration of the former USSR and the virtual economic collapse of Russia led to the cessation of work on advanced fighter projects intended to replace aircraft like the Fulcrum and Flanker, leaving the second generation Su-35 and other Su-27 derivatives as the mainstay of the Russian air forces into the new millennium. The revival of the MiG-29M/MiG-33 in the mid 1990s provided Frontal Aviation with a cheaper, lightweight multi-role fighter to augment the Su-35, but the bigger Sukhoi fighter remains the most important type in Russian service, and with the air arms of various client states. It is believed that the resumption of work on Mikoyan's MiG 1-42 during the 1990s has yet to result in a frontline aircraft, making the Su-35 the most dangerous air defense threat of Russian origin or manufacture.

Above: **Displaying a large 'Paris airshow' number on the fin, '703' comes into land with the airbrake deployed.**

Below: **The Sukhoi Su-35 features small canards to improve low speed handling and maneuverability, which is also enhanced by the advanced new flight control system.**

Above: **The Su-35 is a major improvement over the original Su-27 'Flanker'. With the current willingness for the Russian aerospace industry to sell its latest military hardware many countries can significantly upgrade their capabilities.**

The Eurofighter

Jon Lake

The Eurofighter was designed during the 1980s to meet disparate British, German, Italian and Spanish requirements for an advanced fighter aircraft, primarily for use in the air-to-air role, but with some air-to-ground capability. These were combined in 1983 target requirement and a formal requirement which followed in 1987. The proposed EF 2000 was evaluated against improved versions of the F-15, F-16 and F/A-18 and the French Rafale, and was found to be the only aircraft capable of meeting the anticipated threat. Although Eurofighter's development was long and protracted, the result was that the aircraft is arguably the best multi-role fighter today, and it represents an extremely formidable adversary. Most of the problems it suffered were political, a few were financial, and almost none of them were technical.

Although the Eurofighter was designed to meet what was, in effect, a European Cold War requirement, the involvement of the British RAF always ensured that a rapid deployment, austere base operating capability would be an important priority. This resulted in an aircraft able to provide a credible air defense against the most capable Soviet threat aircraft, wherever they might be encountered. This dramatically improved its export potential, not least because the break-up of the former USSR led to a flood of the most modern Soviet fighters on the export market, many of which found there way into the hands of enemies of traditional

Above: **The second development Eurofighter 2000 is seen carrying four AIM-120s in the recessed fuselage weapon bays and two AIM-9s on the outer pylons. This was the first aircraft to be assembled in the UK.**

Above: **The first two-seat aircraft, ZH590, was flown in its primer. This aircraft was the first with a full avionics set.**

Western allies and customers. The very high cost of the F-22, coupled with severe restrictions placed on its availability by the US Government, have made the Eurofighter a particularly attractive aircraft to a number of export customers.

Above: **Displaying the large wing area of the Eurofighter 2000 to advantage, this photograph also shows the large air intake which has a fixed upper ramp and variable position lower cowl lip.**

Although the original customer nation's requirements dictated that the Eurofighter 2000 would be first and foremost optimized for the air superiority role (in both BVR and close-combat scenarios) the RAF demanded an aircraft with greater versatility, with a comprehensive surface attack capability to allow the aircraft to replace ageing SEPECAT Jaguar ground attack aircraft. In its secondary ground attack role, the Eurofighter can carry seven 1,000 lb bombs in addition to a pair of external fuel tanks and two IR-homing AAMs and four BVR AAMs, and is compatible with a wide range of guided and unguided air-to-surface weapons. It can carry the GEC TIALD pod to designate for its own LGBs.

Even in its lowest drag configuration, with only two IR-homing AAMs outboard underwing, and with four semi-recessed AMRAAMs, the Eurofighter has as many missiles as the Tornado ADV or F-4F ICE, while it can easily carry even more AAMs on its various underwing weapons pylons, totalling more than ten weapons. This gives the aircraft very high combat persistence, enabling it to cope with multiple targets. Eurofighter has thirteen external hardpoints, five under the fuselage (one on the centerline) and four under each wing. Three of the Eurofighter's external hardpoints are 'plumbed' to allow the carriage of auxiliary fuel tanks, giving the aircraft an unparalleled ability to self-ferry.

The EF2000's primary air-to-air weapon remains the US AIM-120 AMRAAM whose active terminal homing offers a useful degree of fire-and-forget capability. It is believed that up to six AMRAAMs can be carried, with two on the main underwing pylons in addition to the four semi-recessed below the fuselage. For shorter range engagements, the Eurofighter 2000 uses IR-homing missiles, fired from rails which are designed to be compatible with both the BAe-Hughes AIM-132 ASRAAM and the AIM-9 Sidewinder (and which are thus compatible with most Western IR homing missiles). The ASRAAM is an agile tail-steered missile with an advanced wide-angle gimballed imaging infra red seeker, which can be cued onto the target by radar, infra-red search and track system, or helmet-mounted sight. This makes it broadly comparable to the AIM-9X Box Office, similarly cueable through a full 180°, and perhaps with a similar ability to target vulnerable areas of the target airframe. The missile armament is augmented by a single 27-mm revolver-fed single-barrel cannon, which offers an excellent compromise between rate of fire and weight of fire, with significantly greater lethality than the fast-firing but lightweight 20-mm Vulcan cannon or the slow-firing Russian 30-mm GSh-30-1. Instantaneous rate of fire is generally close to maximum rate of fire, whereas a Vulcan cannon generally takes several tenths of a second to 'spin-up' to full speed, significant when firing half-second bursts.

Although the Eurofighter 2000 is by no means a small aircraft, and while it is stressed for very high load factors, empty airframe weight is remarkably low. Extensive use was made of advanced materials, with some 70% of the surface area being of carbon fibre composites, 12% of glass reinforced plastic, and only 15% of metal, mainly aluminum lithium, but with a cast aluminum canopy and windscreen surround and with titanium skinned canards, outboard flaperon sections and engine/nozzle fairings.

The Eurofighter 2000 has twin engines to give the best battle damage resistance characteristics and to enhance peacetime flight safety, while also giving the highest possible thrust to weight ratio. The aircraft is powered by a pair of 90 kN (20,000 lb st) Eurojet EJ200 afterburning turbofans. Despite being constrained by the need to produce an engine installationally compatible with the Turbo Union RB199, the EJ200's designers produced a more powerful engine which was lighter, with a lower parts count and lower specific fuel consumption. Of modular construction, the engine is designed for high reliability and low operating and ownership costs, with plenty of potential for growth.
The new engine's thermodynamic cycle is optimized for air combat, and it incorporates various high-tech, state-of-the-art components and materials to ensure low weight and the highest possible performance characteristics. The engine uses single crystal turbine blades, each of which is of wide-chord aerofoil section, with integral blade/disc assemblies created using powder metallurgy.

Below: **The Experimental Aircraft Programme (EAP) was a technology demonstrator for the Eurofighter. Valuable data was gained about the layout, use of carbon-fibres, and fly-by-wire systems.**

To meet the Eurofighter 2000's agility requirements, the aircraft's designers added a high lift wing to the low airframe weight and high thrust engines. Even more significantly, they designed the aircraft to be inherently aerodynamically unstable. The aircraft's delta canard configuration is 'out-of-balance' and the pilot's task in flying it can be likened to sitting on the boot of a speeding Porsche, steering a bicycle backwards by its handlebars. Within a fraction of a second the rear wheel will break away uncorrectably. A human could not react quickly or precisely enough to prevent this. The Eurofighter is similarly unstable in pitch, and a human pilot could not prevent the air-

SPECIFICATION

Eurofighter European Fighter Aircraft 2000

Wing: span 10.50 m (34 ft 5.5 in); wing aspect ratio 2.205; wing area 50.00 m2 (538.21 sq ft); canard foreplane area 2.40 m2 (25.83 sq ft)
Fuselage and tail: length 14.50 m (47 ft 7 in); height about 4.00 m (13 ft 1.5 in)
Powerplant: two Eurojet EJ200 each rated at about 60.0 kN (13,490 lb st) dry and 90.0 kN (20,250 lb st) with afterburning
Weights: empty 9750 kg (21,495 lb); maximum take-off 21000 kg (46,297 lb)
Fuel and load: internal fuel 4000 kg (8,818 lb); external fuel up to one 1500-liter (396-US gal) and two 1000-liter (264-US gal) drop tanks; maximum ordnance 6500 kg (14,330 lb)
Speed: maximum level speed 'clean' at 11000 m (36,090 ft) 2125 km/h (1,147 kt; 1,321 mph)
Range: combat radius between 463 and 556 km (250 and 300 nm; 288 and 345 miles)
Performance: take-off run 500 m (1,640 ft) at normal take-off weight; landing run 500 m (1,640 ft) at normal landing weight
g limits: -3 to +9

Eurofighter

craft's nose from breaking violently upwards - so violently, in fact, that the aircraft would probably break up. Thus the Eurofighter 2000 can only be flown using a sophisticated digital flight control computer, and there is no direct link between the pilot's control inputs and the control surfaces themselves. Even in straight and level flight, the flight control computer has to make continuous control inputs to prevent the aircraft from departing from controlled flight. When the pilot wishes to manoeuvre, he moves the controls as he would in a conventional aircraft, and the computer senses these movements, and modifies its own control inputs to allow the aircraft to respond.

Above: **Creeping up to the camera aircraft, this Eurofighter has the two segment automatic slats on the leading wing edge extended. Low speed handling is excellent.**

The Eurofighter 2000's primary flight controls consist of all-moving canard foreplanes, which operate in unison to provide pitching commands, or differentially to augment roll control. The full-span two-section flaperons similarly operate differentially for roll control, or in unison for pitch control, or for trimming. The single piece rudder operates entirely conventionally for yaw control. Secondary flight control surfaces include the large spine-mounted airbrake, positioned directly behind the cockpit to minimize trim changes on actuation, and the automatic wing leading edge slats, which actuate automatically to provide optimum camber at all angles of attack. The secondary flight control system also incorporates the moveable intake cowls and the nose wheel steering system. The use of digital computers and fibre-optic linkages reduces overall weight, while maximizing speed of response and reliability.

Because the Eurofighter is unstable in pitch, it is very agile (the aircraft wants to pitch its nose upwards all of the time), while the use of an unstable configuration allows the aircraft to use a big, high lift wing with relatively small flight control surfaces, maximizing lift and reducing drag. The Fly By Wire control system also automatically provides gust alleviation, and incorporates *g* and *a* limits which prevent the pilot from over stressing the airframe, or from departing from controlled flight. This gives what are known as carefree handling characteristics, allowing the pilot to make any control input secure in the knowledge that the computer will sort it out, and will maximize turn performance while keeping him safe from departure or of exceeding airframe limits.

The pilot is well protected against the ill-effects of prolonged high g maneuvring with a semi-reclined seat and raised foot position, an advanced anti-g suit incorporating a pressure breathing vest and EAG (external anti g) trousers. Aircrew comfort and safety is further enhanced by the use of direct liquid conditioning to the flying suit, and provision for a full-body NBC suit of advanced design. Aircrew effectiveness is further enhanced by clever cockpit and systems design, which provide an ergonomically laid out and relatively low workload environment, with a high degree of avionics integration and automation to allow single-seat operation of advanced systems. The cockpit canopy and frameless windscreen give the pilot an excellent all-round view of the outside world, while also providing good bird-strike resistance characteristics in the low level environment.

To minimize the amount of time the pilot has to spend looking down into the cockpit, the Eurofighter is equipped with an advanced raster HUD with an unrivaled field of view, while the Helmet Mounted Symbology System presents the pilot with critical flight and weapons aiming information (and even FLIR imagery) when he is looking right away from the line of flight. The helmet also incorporates night vision aids and protection against nuclear flash or laser weapons. Remarkably helmet weight has been kept within tight weight limits, allowing the full helmet to be used even at 9 g. The stick and throttle tops accommodate some 24 fingertip control functions for HOTAS (Hands on Throttle and Stick) operation, while Direct Voice Input (DVI) can be used for certain mode and 'switchology' changes, and for data entry. The pilot can thus ask for fuel status while looking back over his shoulder (receiving the answer by voice), or can change radio frequency, or select a particular weapon or navigation display. Minor problems initially led to Eurofighter entering service with only a modest DVI vocabulary, but this has been steadily increased as operational experience has proved its utility. When the pilot does look down into the cockpit, he is provided with three large colour MFDs (Multi Function Displays) which can present overall tactical situation displays, checklists, systems status or maps and air traffic procedural charts.

Above: **The Italian development aircraft DA3 (serial MMX602) was built by Alenia and became the first Eurofighter to be powered by the definitive Eurojet EJ200s, the two previous aircraft using interim RB199s.**

Above: **CASA of Spain has a 13% share of the Eurofighter program, and is responsible for one development aircraft, DA6, the second two-seater. Spain hopes to buy 87 of the production aircraft.**

Not all Eurofighter 2000s will be fully equipped. German and Spanish aircraft, for instance, do not have the full Defensive Aids

Eurofighter

Sub-System, and it is expected that varying standards of radar and weapons will be supplied to different overseas customers. Thus not every Eurofighter encountered will be as capable as the RAF model used as a baseline for this assessment, although some may be even better equipped and more effective.

Above: **The Eurofighter 2000 shares in the current 'fashion' for canards on modern fighters with the Saab JAS 39 Gripen, Dassault Rafale and Sukhoi Su-35.**

The Eurofighter's single-seat configuration means that the pilot will inevitably suffer from a high workload in some situations, especially if systems failures or battle damage deprive him of some of the aids designed specifically to reduce his workload. The aircraft was designed only to have a low frontal radar cross section, and is not 'stealthy' from all aspects, in the same way as the F-22 or F-117. The aircraft's reliance on external weapons carriage further degrades low observability characteristics, and increases drag.

The Eurofighter's multi-mode ECR-90 pulse-Doppler radar was state-of-the-art during the late 1990s, but now looks perhaps a little dated by comparison with the latest active phased array radar (like those in use in the Rafale, the Japanese F-2 and the F-22, for example). Nevertheless, a Trinational (Anglo-French-German) X-band Airborne Multi function Solid state Active Array Radar (AMSAAR) was launched as early as 1996 for use in Eurofighter and Rafale Mid Life Updates from 2015 onwards. Incorporation of this radar will probably give the production Eurofighter better radar performance than both the F-22, and the ECR.90, like the old Tornado F. Mk 3 Foxhunter before it, has been subject to a constant stream of modifications and improvements.

Augmenting radar as an emission-free target detection, acquisition and tracking sensor is a turret-mounted infra-red seeker and imager mounted on the port side of the forward fuselage, adjacent to the cockpit. This is the Italian FIAR PIRATE (Passive InfraRed Airborne Tracking Equipment) whose supercooled sensor can detect the contrasts in temperature which indicate the presence of an aircraft engine, or an aerodynamically warmed airframe. By not using radar, the EF 2000 pilot ensures that he will not register on his quarries' radar warning receiver, and can use PIRATE to find, close on and engage a target.

The Eurofighter's avionics systems are fully integrated with seven sub-systems sharing information and presenting it to the pilot to give him a comprehensive view of the 'big picture' and doing so with a high degree of redundancy. All of the Eurofighter 2000's basic defensive aids are carried internally, with no need for extra jamming or chaff/flare dispenser pods adding to drag and taking up hardpoints. These aids are fully integrated with the core avionics systems, and form the Defensive Aids Sub-System. This was designed to provide the pilot with all-round prioritized threat assessment, with automatic or manual activation of appropriate countermeasures. The DASS incorporates the usual threat warning systems, ECM and chaff/flare dispensers, but also has a towed radar decoy in the starboard wingtip fairing.

(caused by disagreement between the partners) to unnecessarily increase the cost of the aircraft. Despite this, the Eurofighter 2000 remains a remarkably cheap fighter, in the same broad price range as the F-15 Eagle and much cheaper than the Tornado ADV. This allows it to replace earlier fighters

Above: **Built by DASA of Germany, the first development Eurofighter 2000 is seen testing its RB199s. The aircraft flew first in March 1994 and is used for envelope expansion trials.**

Although not optimized for stealth, the aircraft does incorporate a number of features to minimize radar signature.

Although the Eurofighter enjoys excellent performance characteristics, it does not have the same ability as the F-22 to 'supercruise'. It can sustain supersonic flight without afterburning, but not at quite such high speeds. This is a disadvantage, but is of relatively limited operational significance.

The quadrinational nature of the Eurofighter program led to some unnecessary duplication of effort (not least in the provision of separate flight test facilities and assembly lines), and this combined with delays on very much a one-for-one basis, if required, whereas the very high cost of the 'Silver bullet' F-22 makes it impossible to replace F-15s on much more than a one-for-three basis. Thus an air force equipped with Eurofighters will potentially enjoy a numerical advantage.

When they designed the Eurofighter 2000, the partner nations were determined to produce an aircraft with low cost-of-ownership, as well as with a low initial unit cost. Thus high specified reliability rates (mean times between failures) and component lives were felt to be so important that they were specified as contractual obligations, and severe penalties would have been imposed had

Above: **The Eurofighter will replace the RAF's Tornado F.Mk 3s in the air defense role from around 2005 with ground attack units forming about three years later. The aircraft is designed to have a life of 6000 hours or 30 years.**

they not been achieved. The aircraft was designed for ease of maintenance, with the provision of plentiful access panels, and with the location of key servicing items at an easy height for groundcrew access. The aircraft was designed to operate with a minimum of external ground support equipment, and maintenance man hour per flying hour targets were specified contractually. The result is an aircraft which is extremely maintainable and repairable, giving unparalleled availability rates and short turnaround times. These features also confer on the Eurofighter 2000 the ability to operate from relatively primitive sites, including forward airfields and motorway strips.

But the Eurofighter's relatively low price tag does not infer any lack of capability. Several Eurofighter equipment items (including the advanced HUD) were adopted for the F-22, and the aircraft has thirteen external stores stations, and carries some 9,000 lb of internal fuel!

While the Eurofighter does not enjoy quite such all-round low-observability as the F-22, its frontal radar cross section is very small (even when carrying weapons) and its supersonic acceleration is impressive. Comprehensive active and passive defensive aids are carried, reducing vulnerability to a return missile shot. Eurofighter's frontal aspect BVR 'reach' is thus considerable, and the F-22 pilot will have to use every advantage available to him to beat this potent threat. Inside visual range, the Eurofighter is relatively small and hard to see, and its canard foreplanes and unstable aerodynamic configuration make it extremely agile. The Eurofighter pilot has a sophisticated helmet mounted sight, and the use of Direct Voice Input allows him to remain focused on the target at all times, maximizing situational awareness. The aircraft's high thrust-to-weight ratio, high-lift wing, and both generous *g* and *a* limits combine to make it a very difficult opponent in a slow-speed or turning dogfight.

MiG-29M 'Fulcrum'

Jon Lake

The MiG-29 was designed during the 1970s as a replacement for the MiG-21 and MiG-23 with the Soviet Union's tactical air forces assigned to Frontal Aviation. Entering service in 1983 it was intended as a Soviet equivalent of, and counter to, Western aircraft like the Lockheed Martin (General Dynamics) F-16. Very widely exported before the break-up of the USSR, many Soviet users re-exported their aircraft to rationalize their air arms, or to provide aid with debt resettlement. From the late 1980s, Mikoyan began to offer a range of upgrades for the MiG-29, radically improving its capability and increasing its versatility.

The MiG-29 remains an extremely effective counter air fighter, broadly comparable to aircraft like the F-16 and F/A-18, and in some ways superior, in the pure fighter role. The MiG-29 is helped by its small size and relatively low frontal radar cross section, and by the safety and survivability advantages conferred by its twin engines. These endow on the MiG-29 a very high thrust-to-weight ratio, which complements a high lift and low drag wing. These characteristics give the MiG-29 superb turning performance.

The MiG-29's superb wing and high lift fuselage, LERXes and twin fins also conferred an

Above: **With a quadruplex analog fly-by-wire control system, modernized cockpit, airframe changes and increased fuel capacity the MiG-29M is a great improvement over the original MiG-29.**

MiG-29M

unmatched high a, slow speed capability. The MiG-29's resilient engines and deceptively simple intake design allowed the engines to continue running even at extreme angles of attack, and in the face of major airflow disturbances in the intakes, allowing the aircraft to perform maneuvers like the tailslide and cobra.

The MiG-29's sophisticated electro-mechanical flight control system gave the pilot the ability to exceed normal *g* and a limits briefly, entering those areas of the flight envelope in which departure becomes progressively more likely, and which are normally fenced off by hard flight control system limits. Faced with the choice between exceeding *g* and a limits or losing the fight, flying into the ground or failing to evade the incoming missile, the MiG-29 pilot could actually pull through the stick-stops which marked these soft limits, while an F-16 pilots flight control computer would not allow him to exceed certain hard limits in any circumstances.

The MiG-29 was among the first frontline fighters to feature an in-service helmet sight, which, combined with R-73 (AA-11 Archer) missiles, gave a remarkable degree of off-boresight capability. The short-range armament was backed up by a pair of BVR capable R27 (AA-10 Alamo) missiles, broadly equivalent to late mark AIM-7 Sparrows. The aircraft was also ground-breaking in that it featured a combination of target detection, acquisition and tracking sensors, which could be used individually or in concert. The use of IRST with laser ranging made it possible to run an intercept from acquisition to engagement without making tell-tale electro-magnetic emissions, which might be detected by the target's RHAWS, providing a useful alternative to radar.

The MiG-29's low price, particularly after the collapse of the USSR, when Russia and other newly independent states were starved of cash, made it an extremely affordable fighter, while the aircraft's cost of ownership was also relatively low. The basic MiG-29 was easily maintainable, repairable and damage resistant, and was able to operate from primitive sites, making it particularly attractive to less advanced air forces. Despite its low price, the MiG-29 was well equipped, with RHAWS, data link, and other advanced equipment not then being offered as standard on similar Western fighters.

The baseline MiG-29 was far from perfect, however, and was handicapped by several major flaws. The aircraft suffered from a serious lack of range and endurance, while its systems and avionics were poorly integrated, imposing a high cockpit workload on the pilot. He was further hampered by having to place an undue reliance on external agencies (GCI or AWACS) for threat and target prioritization. The lack of a modern FBW control system meant that simply flying the aircraft and operating its systems demanded constant attention, reducing the pilot's capacity to maintain situational awareness.

The MiG-29's engines initially suffered from an unacceptably short time between overhaul, and even today are more maintenance intensive than equivalent Western fighter engines. The engines are also relatively smoky using certain fuels, giving the aircraft an unhelpful smoke signature under certain conditions. The BVR armament is relatively poor by modern standards, and the internal cannon carries only 149 rounds of ammunition and has a very short barrel life. The weapon is surprisingly accurate, however, despite the unsophisticated gunsight. Carriage of external fuel either prevents use of the gun (if a tank is carried on the centerline) or takes up BVR weapons stations (if tanks are carried underwing). The aircraft has no real precision attack capability in its basic form, although this has been addressed in upgrades.

Following the collapse of the USSR, MiG-29 operators suffered from poor spares and service support, but new arrangements were soon made, and by the late 1990s, support infrastructure had improved quite dramatically.

The main shortcomings of the basic MiG-29 were addressed in the MiG-29M. The most important priority was to enhance the aircraft's multi-role capability, through the introduction of new avionics and systems, and by making the aircraft compatible with a range of advanced air-to-surface weapons. Initially (in a prototype given the internal OKB designation 9-14) the Bureau simply added a large external avionics pod to the existing MiG-29S, but it soon became apparent that this would degrade performance to an unacceptable degree, even if higher thrust engines were installed. It was decided that a relatively modest redesign was the best way forward, offering the opportunity to address the aircraft's lack of range and short service life.

While retaining the existing MiG-29's external configuration, the MiG-29M was subjected to a thorough revision. The airframe was strengthened, and extensive use was made of welded aluminum lithium components and sub-assemblies. These reduced the need for conventional fasteners, sealants and rivets, while saving weight and providing increased internal volume for fuel and avionics. Increased use was also made of composites, further saving weight and increasing strength and rigidity. The redesigned fuselage is built around a new aluminum lithium fuel tank in the centre section and extending into the LERXes, replacing the auxiliary overwing air intakes of the basic MiG-29. This was made possible by replacing the solid anti-FOD intake doors (usually closed on take off and landing) with gridded and close-meshed screens which fulfilled the same function, while still allowing adequate airflow to the engines. The new tanks gave a 25% increase in internal fuel capacity, bringing the total to somewhere in line with that of the F/A-18 (and higher than that of the Dassault Rafale). The increased fuel capacity brought about a useful increase in range, radius and endurance figures.

The redesigned airframe of the MiG-29M also incorporated a redesigned fuselage spine, of increased internal volume. This accommodated some of the increased fuel capacity, but also housed an advanced new Gardeniya active jammer, and flush-fitting chaff/flare dispensers. These carried 120 cartridges, more than twice the number carried by the basic MiG-29 in the dispensers in the fin root leading edge extensions. While the structural changes to the MiG-29M did not result in a major increase in empty weight, the increased fuel tankage resulted in a significant increase in the potential maximum take-off weight, which was further increased by the addition of extra underwing weapons pylons, which were also re-stressed for the carriage of heavier loads. In order to exploit this potential, the MiG-29M was fitted with a strengthened undercarriage, and was re-engined with more powerful RD-33K turbofans. These had a redesigned fan for greater mass flow, and improved metallurgy (including single crys-

SPECIFICATION

Mikoyan MiG-29M

Wing: span11.36m (37 ft 3.25 m); aspect ratio 3.4; wing area 38.00 m2 (409.04 sq ft)

Fuselage and tail: length 17.37 m (57 ft 0 in) including probe; height 4.73 m (15 ft 6.2 in); tailplane span 7.78 m (25 ft 6.25 in); wheel track 3.10 m (10 ft 2 in); wheel base 3.67 m (12 ft 0.5 in)

Powerplant: two Leningrad/Klimov (Isotov/Sarkisov) RD-33K turbofans rated at 53.95 kN (12,125 lb st) dry, 86.33 kN (19,400 lb st) with afterburning, and with an 'emergency regime' rating of 92.22 kN (20,725 lb st)

Weights: operating empty 10900 kg (24,030 lb); normal take-off 15240 kg (33,598 lb); maximum take-off 18500 kg (40,785 lb)

Fuel and load: internal fuel 5000 kg (6,250 litres; 1,651 US gal); external fuel one 1500-1520 liter (396-402 US gal) centerline tank and (on some Soviet aircraft) two 1150-liter (303-US gal) underwing ferry tanks; maximum ordnance 4500 kg (9,921 lb)

Speed: maximum level speed 'clean' at 11000 m (36,090 ft) 2445 km/h (1,319 kt; 1,519 mph) or at sea level 1500 km/h (810 kt; 932 mph)

Range: 2000 km (1,080 nm; 1,243 miles) with internal fuel; 3200 km (1,728 nm; 1,988 miles) with external fuel tanks

Performance: maximum rate of climb at sea level 19800m (64,961 ft) per minute; service ceiling 17000 m (55,775 ft); take-off run 250 m (820 ft) at normal take-off weight; landing run 600 m (1,969 ft) at normal landing weight with brake-chute

g-limits: +9 below Mach 0.85 and + 7 above Mach 0.85

MiG-29M

Above: **The appearance of Russian combat aircraft at western airshows is today common. Here one of the prototype MiG-29Ms is displayed at Farnborough, carrying Vympel R-77 'AMRAAMski' missiles.**

Right: **The cockpit of the MiG-29M is advanced when compared with most Russian fighters but not when compared to the latest western fighters. Many analog dials are still visible as well as the multi-function displays.**

tal blade technology) to allow higher operating temperatures. They also incorporated full authority digital control units, giving a total increase in thrust of about 5 kN (1,100 lb st) per engine. Engine life was also increased. The new RD-33K is interchangeable with the basic RD-33, and could therefore be used to improve the performance of existing MiG-29's.

In addition to the structural changes and the change of powerplant, the MiG-29M airframe also incorporated a host of aerodynamic refinements. The prominent leading edge root extensions (LERXes) were re-profiled, with a smaller radius on the leading edge, making them appear much sharper. These generated stronger, more powerful vortices, improving handling characteristics at higher angles of attack. The ailerons were extended further outboard, improving control authority in roll, while the tailplanes were increased in chord and given a dog-tooth discontinuity on the leading edge, giving greater control authority in pitch (when actuated symmetrically) and in roll (when actuated differentially). The dogtooth generated vortices which helped keep flow at high angles of attack. The original small airbrakes above and below the fuselage boat tail were replaced by a much larger and more powerful dorsal airbrake, located well aft on the spine. This allowed faster deceleration, and was stressed for use at higher speeds, while its more forward location resulted in smaller pitch changes on actuation.

Whereas the original MiG-29 had used a conventional electro-mechanical flight control system (albeit with some fairly sophisticated features, including an aileron/rudder interconnect, which progressively fed in at high angles of attack) the MiG-29M introduced an analog fly by wire control system, with four channels for pitch, and three for roll and yaw. Mikoyan retained a mechanical back-up system, and programmed in soft limits, which could be over-ridden by the application of increased stick force, allowing the pilot to briefly exceed *g* or *a* limits in order to avoid a missile, or terrain, or to get his nose (or helmet sight) onto target for a snap missile shot. The use of soft limits had been a major advantage of the original MiG-29's control system. An analog system was used because it was felt to be more reliable, and more resistant to damage from EMP, and the disadvantages of higher weight were simply accepted.

Above: **With twin fins and twin engines under the wing, the MiG-29 can at certain angles look like the bigger Sukhoi Su-27 'Flanker'. While the latter aircraft was designed for air-to-air combat the later MiG-29M is a true multi-role aircraft.**

Although it marked a major improvement over the analog cockpit of the basic Fulcrum, the glass cockpit of the MiG-29M is primitive by the latest Western standards. In some ways, the new cockpit is as advanced as anything in the West. Its two multi-function display screens are mounted high on the panel, close to the HUD (and thus to the pilot's eye-line) and are operated entirely by HOTAS controls on the throttles and stick, with no input buttons around the screens themselves. Where the displays are primitive is in the fact that they are simple raster-scanned monochrome CRTs, and not full-color high-brightness LCDs.

Some suggest that monochrome displays are easier to interpret and less distracting, and that they force display designers to make symbology clear and unmistakable, without using color as a crutch. Others suggest that monochrome displays are easier to use under combat conditions, especially under *g*, when the pilot may be beginning to grey out. Apart from the display screens, the MiG-29M cockpit remains almost unchanged, cluttered with traditional analog instruments.

New avionics systems, including a new electro-optical complex, incorporating IRST, laser and a TV camera, gave compatibility with a wide range of new air-to-ground weapons, including TV, laser and radar guided bombs and missiles. This marked a major improvement over the baseline MiG-29, which carried only dumb bombs and unguided rockets in its limited air-to-ground role. MiG-29M weapons include the laser-guided Kh-25ML (AS-12Kegler), the similarly guided Kh-29L (AS-14 Kedge), and the KAB-500l laser guided bomb, as well as TV guided Kh-29T ASMs or KAB-500KR bombs. An extra pair of outboard underwing pylons were added on the MiG-29M, bringing the total to eight, in addition to the centerline hardpoint. The four inboard pylons were stressed for the carriage of loads of up to 1000 kg (2,205 lb) each, with the four outboard pylons being stressed for loads of up to 500 kg (1,102 lb). Maximum total warload is 4500 kg (9,920 lb). The provision of four underwing hardpoints dramatically improved combat persistence, allowing the aircraft to carry up to eight AAMs, while six

MiG-29M

Above: **To improve landing distances, the MiG-29M can deploy a pair of cruciform braking parachutes. Two 140 squ ft area chutes replace the single 183 sq ft chute of the MiG-29, the extra area due to the increased weight.**

could be carried even alongside a pair of external underwing fuel tanks. More importantly, the MiG-29M can carry four R-27 (AA-10 Alamo) BVR missiles instead of only two, and these can be the new extended range R27RE version. Alternatively, the aircraft can carry up to eight of the new R-77 (AA-12 Adder) active radar homing BVR AAMs, whose performance initially led to them being dubbed AMRAAMski in the West. These have unusual 'potato masher' latticed control fins, which impart massive control forces for their small size (since each gridded box incorporates a large area of aerofoil) and with relatively low actuator forces. They are thereby rendered extremely effective at high angles of attack.

Unlike previous MiG-29 variants, the MiG-29M has a significant SEAD or Wild Weasel capability, and can carry up to four Kh-25MP or Kh-31P anti-radar missiles. The Kh-25MP can be fired automatically by the new L-150 Pastel RHAWS, which can control the launch sequence and accurately cue each missile onto a separate target.

The basic MiG-29's N-019 'Slot Back' pulse Doppler radar has good performance characteristics, but always lacked flexibility. Primarily an air-to-air tool it lacked advanced air-to-ground modes, while a lack of processing capacity precluded onboard target and threat prioritization, forcing the pilot to depend on GCI controllers in most circumstances. The MiG-29M introduced a new N-010 radar which used an AN/APG-65 type planar array antenna in place of the twist cassegrain antenna of the earlier radar. The new radar offered a 25% increase in range, and introduced a range of air-to-ground modes, including terrain following, uniform scale radar mapping (real beam and synthetic aperture) and freeze-and-zoom mapping. The radar may have been influenced by the F/A-18's AN/APG-65, details of which had been obtained by the USSR through espionage.

Having successfully passed its initial state acceptance trials in the early 1990s, the MiG-29M entered a period of limbo, with completion of development testing waiting for further funding which was not granted until 1995. This delay was imposed by the restructuring of Russia's defenses following the end of the Cold War, during which Sukhoi's greater political influence enabled it to monopolize the limited resources available for new aircraft projects, and during which the Su-30, Su-33 and Su-35 received funding in preference to the MiG-29M and its maritime sibling, the MiG-29K. Funds were eventually released at the urging of the Russian Ministry of Defense.

Unconfirmed reports suggest that the MiG-29K has been resurrected. This carrier-capable variant is broadly equivalent to the MiG-29M, with the same radar, increased fuel capacity, higher thrust engines and multi-role avionics and weapons systems. The aircraft has a retractable inflight refueling probe fitted as standard, and is equipped for the carriage of a buddy refuelling pod. If the MiG-29K is available to the Russian Navy it could replace or augment the Su-33 aboard the *Admiral Kuznetsov* giving greater strike capability, and providing larger aircraft numbers for the same hangar and deck space. The MiG-29K would be an ideal aircraft for carrier-operating nations like India and Thailand, offering a great deal of multi-role capability in a relatively compact airframe. The aircraft can take off in a very short distance using a ski-ramp, and does not require a catapult. It recovers using conventional arrestor gear. The MiG-29K's performance characteristics differ little from those of the MiG-29M.

Mikoyan began offering significant upgrades to existing baseline MiG-29 users during the early 1990s, offering R-77 (AA-12) missiles, inflight refueling probes, and radar upgrades. Alpha and g limits were increased slightly by modifications to the electro-mechanical flight control system. Engine life and thrust have been increased, while the smoke signature has been reduced. The aircraft can also be given compatibility with a wider range of air-to-ground weapons, including PGMs. These upgrades are cheap and proven, and can be incorporated very quickly. Unless you have irrefutable evidence to the contrary you must assume that any MiG-29 that you encounter could be thus upgraded. At air combat ranges there is no significant external difference between the basic MiG-29 and the MiG-29M/MiG-33, which is (as has been outlined above) a very much more capable aircraft. With this in mind, you should assume that any Fulcrum encountered is actually a MiG-29M, unless you know that you are engaging a 'Slot Back' equipped Fulcrum.

Above: **The large intakes for the Klimov RD-33K turbofans and the compact nature of the aircraft are evident, but the weight increase over the MiG-29 has demanded a reinforced undercarriage which is externally unchanged.**

The best way to deal with a MiG-29 threat is to destroy it at maximum range, if rules of engagement permit. If forced into a close-range engagement keep your speed and energy high and be aware of the angular displacement at which his helmet sight allows him to launch a missile. On no account enter a low-speed turning fight, and do not attempt to use the vertical plane at low altitudes. The basic MiG-29's limited fuel capacity means that he will almost certainly 'bingo' before you do, and a valid tactic may be to force him to run low on fuel and pounce as he attempts to disengage. Despite its age, price, and simplicity, the Mikoyan MiG-29 remains a formidable adversary and should not be underestimated! The aircraft has been very widely exported and may represent the most likely threat aircraft in many scenarios.

Above: **Having just released the brakes, a prototype MiG-29M accelerates down the runway for another display. The lack of the overwing auxiliary intakes, a characteristic of the earlier MiG-29s, can be seen in this shot.**

Dassault Rafale

Paul Jackson & David Donald

Now flying in pre-series form, the Dassault Rafale is a French combat aircraft with French engine and French avionics: a flagship for its home country's military industries and an affirmation of French determination to be second to none in the Europe of the 21st century.

Following its unveiling at Dassault-Breguet's St Cloud experimental plant in Paris on 14 December 1985, the prototype Rafale A was carried by road to the company's flight-test center at Istres. Preparations complete, Guy Mitaux-Maurouard took the aircraft aloft for the first time on 4 July 1986, achieving Mach 1.3, 36,000-ft altitude and maneuvre loads of 5 g on this one-hour sortie.

Leading particulars included a span of 36 ft 9 in (11.20 m), length 51 ft 10 in (15.80 m), wing area 506 sq ft (47 m2), maximum speed Mach 2 and an empty weight slimmed to 20,945 lb (9500 kg), while the F404-400 reheated turbofans delivered 15,422 lb st (68.60 kN) each.

Early missions were concerned with opening the flight envelope, the 90th flight, on 13 January 1987, being followed by a brief lay-up for revised instrumentation to be installed. On 4 March 1987, during flight No. 93, a stabilized speed of Mach 2 was demonstrated at 42,650 ft (13000 m). In addition to being above the Mach 1.8 required by the official specification, this was a convincing vindication of air intake and forward fuselage design.

Launching an important phase of development for the naval variant, for which Yves Kerhervé was project pilot, A 01 made a series of approaches to the dummy deck at Nîmes-Garons naval air base, followed by

Above: **Destined to be the prime combat aircraft of the Armee de l'Air well into the 21st Century, the two-seat Rafale B was designed as a combat capable conversion trainer for the single seat C.**

Dassault Rafale

practice approaches to the carrier Clemenceau on 30 April 1987. Though unable to touch down on the vessel – having no hook or strengthened undercarriage – the aircraft was of great value in simulating handling on the approach. Flying at angles between 16° and 18°, the Rafale was able to cross the stern at about 120 kt (222 km/h), or 5 kt (9 km/h) slower than the Super Etendard. At length, A01 bowed out in fine style when it led a well-publicized formation of all four pre-series Rafales on 24 January 1994 during its 865th and last flight.

Above: **Flying over its natural territory, the sea, one of the prototype Rafale Ms shows the compact lines and large fin of Dassault's latest combat aircraft. Time will tell if the Rafale is the last, as a merger with Aerospatiale may be in the future.**

A French government decision in principle to turn the Rafale A into an operational combat aircraft was announced on 14 February 1987 and led directly to formation on 8 April of ACE International. Comprising Dassault-Breguet, SNECMA and Thomson-CSF, this consortium was dedicated to launching Rafale as the self-styled Avion de Combat Européen (ACE) and facilitating participation by aerospace firms in other countries. Belgium, Denmark, the Netherlands and Norway were among the smaller NATO members courted by ACEI, but all eventually chose to extend the lives of their F-16 Fighting Falcons instead of buying a new fighter in the late 1990s. The contract included one prototype (at first planned to be a two-seat aircraft) and options for four more. In its definitive form the land-based (ACT) aircraft had been known since early 1987 as the Rafale D, while the navalized ACM was Rafale M. One of the last-minute changes demanded by the military purchasing authority, DGA (Délégation Générale pour l'Armament), before approving the design was increased stealth characteristics – though these are by no means as pronounced as on the F-22 and are compromised by external stores stowage – resulting in the 'D' being hailed by its manufacturer as the Discret model. Thereafter, however, the air force's two versions of Rafale received new appellations, reflecting the sub-variant letters which had become traditional for the Mirage series. The Rafale D became Rafale C in its single-seat form and Rafale B as a two-seat operational trainer, neither having any connection with the unbuilt projects which had previously carried those suffixes.

Rafale C wing span, including the tip-mounted MATRA Magic 2 missiles, is now 35 ft 9 in (10.90 m), length 50 ft 21⁄4 in (15.30 m) and wing area 495 sq ft (46 m2). It began with a basic empty weight of 8.6 tonnes (18,959 lb), which grew by the time of its first flight to 19,973 lb (9060 kg). However, more extensive use of composites materials kept the weight almost the same as the first Rafale B project, despite a modest increase in size.

Half the Rafale's fuselage is of carbon-fibre construction, notably around the cockpit and on upper and lower surfaces, while Kevlar covers the nose and extreme rear. The pilot enjoys good all-round vision from a high-placed Martin-Baker Mk 16 zero-zero ejection seat (built under license by SEMMB) inclined at 29°. Wings, fin and canards are also primarily of carbon-fibre, their control surfaces actuated by hydraulic power at 4,000 lb/sq in (280 bars). The multi-spar wing has elevons along its entire trailing edge, these divided in two (three on Rafale A) at approximately mid-span. Leading-edge slats, built of titanium and also reduced from three to two, open automatically at high angles of attack to provide additional lift, while foreplanes deflect upwards 20° for a similar reason when the undercarriage is lowered. Twin nosewheels characterize the current Rafale, A 01 having single wheels throughout. Able to withstand no-flare landings with a sink rate up to 13 ft (4 m) per second, the Messier-Bugatti landing gear with its carbon brakes allows the Rafale to operate from short runways. Take-off roll with a full combat load is some 1,969 ft (600 m), or one-third less with air-to-air armament.

Designated a multi-role aircraft, Rafale is expected to mount a Thomson-CSF/Dassault Electronique RBE2 radar in the nose. Falcon 20 No. 104 of the CEV trials establishment was fitted out as the initial air testbed for RBE2 and flew for the first time on 1 April 1992 – with an empty nose. After equipment installation, it began operations on 10 July the same year out of Brétigny-sur-Orge, immediately south of Paris. Another Falcon 20 and a Mirage 2000 were next to receive RBE2 but, at length, radar and Rafale met for the first time as two-seat prototype B 01 took to the air after a retrofit on 7 July 1993.

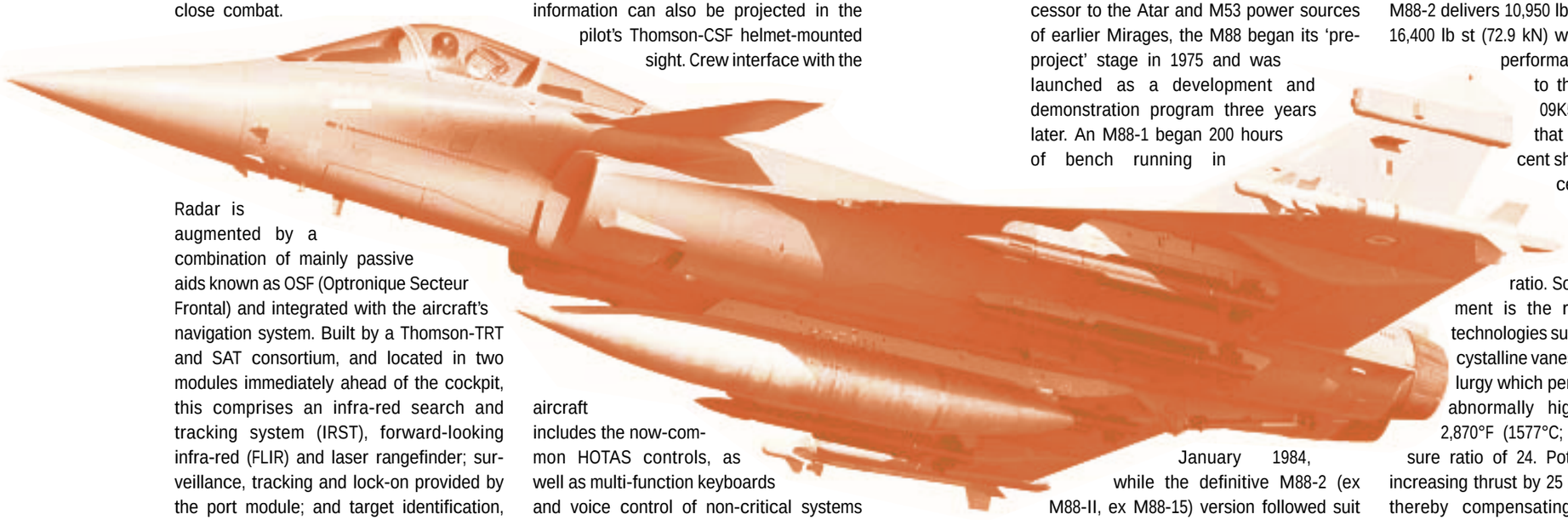
RBE2 derives its designation from a two-dimensionally, electronically-scanned antenna (Radar à Bayalage Electronique deux plans) based on T-CSF's RADANT technology. In simple terms, it will be the first operational European fighter radar in which electronic direction of the beam replaces the traditional nodding antenna. Greatly increased beam agility and data processors performing one billion operations per second allow the Rafale to interleave functions so, for example, undertaking a terrain-following flight while simultaneously tracking up to eight enemy aircraft and launching self-defense missiles at those presenting the greatest threat. For air-to-surface operations, the low-probability-of-intercept radar has terrain-following, terrain-avoidance and threat-avoidance capability, allied to modes

Above: **Seen carrying AAMs on the wingtip rails, external fuel tanks on the centerline and outer wing pylons and APACHE stand-off missiles on the inner pylons, this Rafale is configured for a low level strike mission.**

Dassault Rafale

for high-resolution mapping, updating navigation, target aiming, search and tracking of moving or fixed targets and ranging. In naval operation, long-range detection and training of shipping can be a prelude to attacks with surface-skimming missiles.

During air-to-air combat, RBE2 will search above or below the horizon out to 54 nm (100 km) and automatically select high, medium or low pulse-repetition frequencies to optimize detection. Targets are interrogated for IFF, while a dogfight mode is selected for close combat.



Radar is augmented by a combination of mainly passive aids known as OSF (Optronique Secteur Frontal) and integrated with the aircraft's navigation system. Built by a Thomson-TRT and SAT consortium, and located in two modules immediately ahead of the cockpit, this comprises an infra-red search and tracking system (IRST), forward-looking infra-red (FLIR) and laser rangefinder; surveillance, tracking and lock-on provided by the port module; and target identification, analysis and optical identification by the starboard. Range under optimum conditions is 38-43 nm (70-80 km). Award of contracts for OSF were delayed until early in 1991, with the result that test flying will begin only in 1996 and installation in the Rafale three years later.

Data from these and other systems is presented to the pilot via the Sextant Avionique CTH3022 wide-angle, holographic HUD and four other colour screens in the modern 'glass' cockpit. Between the knees is a navigation and radar display, while on either side of the instrument panel is a 5-in (12.7-cm) touch-sensitive liquid crystal display (LCD), the fourth screen being termed the 'head-level', as it is located below the HUD and shows the tactical situation including OSF outputs. Flying instruments are normally represented on the port LCD, its companion showing status of the engines, fuel, hydraulics and other systems. Essential information can also be projected in the pilot's Thomson-CSF helmet-mounted sight. Crew interface with the aircraft includes the now-common HOTAS controls, as well as multi-function keyboards and voice control of non-critical systems (including radio) as the first practical application of trials begun with a Mirage IIIR at CEV, Brétigny-sur-Orge, in July 1982.

Communication between avionics is via a digital databus which permits installation of a highly automated countermeasures system designed specifically for the Rafale. SPECTRA (Système pour la Protection Electronique Contre Tous les Rayonnements Adversés - system for electronic protection against all adverse radiation) is a wholly internal countermeasures suite compiled by Dassault Electronique, Thomson-CSF and MATRA. The 551-lb (250-kg) SPECTRA package includes infra-red detection, decoys, laser warning, electromagnetic detection & jamming and the VOIR missile-approach warning system.

As implied above, the Rafale is the first – and so far only – application of SNECMA's new M88 twin-spool turbofan. Intended as successor to the Atar and M53 power sources of earlier Mirages, the M88 began its 'pre-project' stage in 1975 and was launched as a development and demonstration program three years later. An M88-1 began 200 hours of bench running in January 1984, while the definitive M88-2 (ex M88-II, ex M88-15) version followed suit on 27 February 1989, a year to the day before its first flight in the Rafale A. Nine ground-running M88-2s were funded for a 5,500-hour program, although the last (No. 209) was fitted in Rafale A 01 and flew seven sorties up to 29 March 1990 (see above). It was then replaced by engine No. 220, the first of 15 flight-standard M88-2s ordered to provide a pool for the development Rafales.

Above: **Trials aboard the French carrier *Foch* were conducted with the Rafale M prototypes began during 1993, after simulated carrier operations in America. The naval Rafale has a 'beefed up' undercarriage and an arrestor tail hook for carrier operations.**

After allowance for installation losses, the M88-2 delivers 10,950 lb st (48.7 kN) dry and 16,400 lb st (72.9 kN) with afterburner. This performance is comparable to the Mirage F1's Atar 09K50 turbojet, except that the M88 is 40 per cent shorter, weighs 45 per cent less and reflects an 88 per cent improvement in thrust:weight ratio. Some of that improvement is the result of advanced technologies such as cooled, micro-cystalline vanes and powder metallurgy which permit operation at the abnormally high temperature of 2,870°F (1577°C; 1,850°K) and pressure ratio of 24. Potential is inbuilt for increasing thrust by 25 per cent at mid-life, thereby compensating for the weight-growth common to most combat aircraft. This will be accomplished in two stages: M88-3 with a new low-pressure compressor, and M88-4 having a redesigned low-pressure turbine and afterburner.

Carrying up to 13,228 lb (6000 kg) of external stores on 14 attachment points, plus an internal GIAT DEFA791B rapid-firing 30-mm cannon, the Rafale C has a formidable

Dassault Rafale

Above: **The one-off Rafale A served as the Avion de Combat Experimentale (ACX) demonstrator, proving the basic Rafale design, fly-by-wire system and test flying the SNECMA M88-2 engine. It was retired in 1994.**

armory. As an interceptor, a maximum of eight new MATRA MICA air-to-air missiles may be carried, while still leaving room for 440-Imp gal (2000-liter) drop tanks on two of the five 'wet' pylons. Ordered specifically for the Rafale under a development contract of April 1987, MICA (Missile d'Interception, de Combat et d'Autodéfense) will allow the Armée de l'Air to dispense with the Magic/Super 530 mix of the Mirage 2000C, as it is available either as an infra-red homing weapon with a SAT/MATRA sensor, or may be fitted with the equally 'fire-and-forget' Dassault Electronique AD4A active radar head. The last-mentioned firm emerged through renaming of Electronique Serge Dassault in 1990, at which time Louis Breguet was deleted from the aircraft company title, which became Dassault Aviation. Air-to-ground weapon loads include the new MATRA APACHE stand-off modular system and prospective Aérospatiale ANS anti-ship missile, as well as Aérospatiale AS30L laser-guided missiles and similarly directed bombs (LGBs). When armed to the teeth, 16 500-lb (227-kg) bombs, two self-defense MICAs and two 275-Imp gal (1250-liter) tanks are one possible load. Maximum versatility is represented by a mixture of four MICAs, two 2,204-lb (1000-kg) LGBs, two AS30Ls, a FLIR pod, laser designation pod and one 440-Imp gal (2000-liter) tank; maximum destruction by a single 300-kt Aérospatiale ASMP stand-off nuclear bomb. A long-range naval mission might employ two ANS missiles, four MICAs, two of the smaller drop tanks and one large. Pressure refuelling takes between four minutes for the internal tanks holding somewhat in excess of 1,171 Imp gallons (5525 liters) and seven minutes if the maximum 1,452 Imp gallons (6600 liters) of external capacity is attached. For aerial deliveries, a fixed refuelling probe will be fitted, both operators having elected to forego the more complex retractable probe originally specified.

The carrier-capable Rafale M incurs a 1,675-lb (760-kg) weight penalty because of its role. A strengthened main undercarriage increases allowable sink rate to 21 ft (6.5 m) per second and includes a catapult launching bar protruding from the 'jump strut' nosewheel leg, while a hydraulically operated arrester hook replaces the spring-loaded airfield arrester unit on the land-based version. Local airframe strengthening surrounds the undercarriage and hook, and there is an integral folding ladder for the pilot. Avionics changes are few, but include deck landing aids and an interface for aligning the aircraft's navigation system with that of the parent vessel.

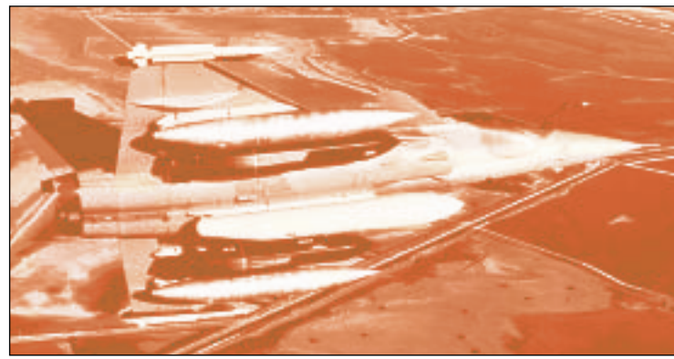
The ingenious nosewheel leg has its shock absorber under tension until the end of the catapult run, when it is released to force the nose upwards as the aircraft clears the deck. The effect is the same as the Sea Harrier's 'ski-jump' in that it reorientates the aircraft to the optimum climb-out angle and increases the permissible take-off weight. Of further note is the fact that carbon-fibre wing construction is incompatible with insertion of hinges, so Rafale Ms will be stowed aboard their two new nuclear-powered carriers without benefit of the usual space-saving measure. Rafale M will have 80 per cent structural and equipment commonality with the C version, rising to 95 per cent for systems, a high standard of corrosion protection being common to both.

Revealed at St Cloud on 29 October 1990, Rafale C No. 1 was seen to have several changes of detail from its progenitor. Slightly smaller and lighter, as discussed above, it has more rounded wing root fairings (for increased stealthiness), profile changes around the junction of fin and rear fuselage, a gold-coated canopy (again to dissipate radar signals) which now lacks a fixed rear section, and a coat of radar-absorbing dark grey paint. The fin shape has also been revised, and it carries a pod close to the top to house the radar warning receiver and lateral sensors for the missile approach warning system. Also associated with the SPECTRA self-defense suite are forward extensions to the canards which act as mountings for antennas.

Canards themselves are larger and constructed of diffusion-bonded titanium, instead of less-strong carbon composites. Nevertheless, use of new materials is increased from 35 per cent by weight to 50 per cent of the production Rafale. The cannon port – now on the starboard side – has above it a small, curved streak running from the wingroot leading edge to the outer intake wall.

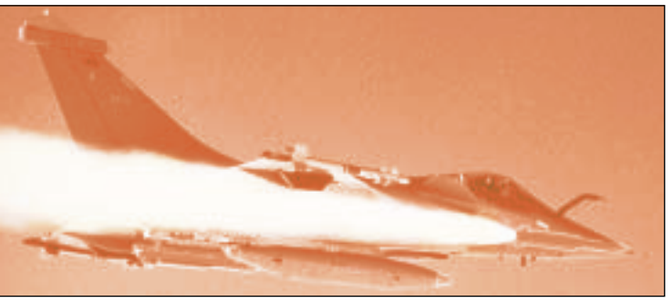
Quickly dismantled, C 01 was delivered by road to Istres on 31 October to begin ground running and vibration tests. A targeted first flight date in February 1991 was missed as a result of minor technical snags, but after a fortnight of taxiing trials the aircraft was taken aloft by Mitaux-Maurouard on 19 May 1991. In a busy one-hour sortie, it achieved Mach 1.2 with only one afterburner operative, supersonic cruise in maximum dry thrust and a landing run of 3,000 ft (914 m) after a 125-kt (232-km/h) approach at slightly less than the optimum nose-up angle.

For this, the debut of a Rafale with M88s in both engine bays, the powerplants were temporarily restricted to 16,186 lb st (72.00 kN). C 01 took time off from its test schedule to make a public appearance before President Mitterrand at the inauguration of the Paris air show on 13 June 1991, this only the 17th time it had flown.



Above: **The two-seat Rafale B 01 is fitted out with the RBE2 radar and the Spectra automated and integrated defensive system. Costing more than the single-seater, the high workload in combat prompted adoption of the 'B' for combat missions.**

Otherwise known by its flight-test callsign F-ZWVR, C 01 achieved its 100th test-flight on 12 May 1992 and underwent the Rafale's first official evaluation at Istres between 15 and 26 June the same year. By then, howev-



SPECIFICATION

Dassault Aviation Rafale C

Wing: span 10.90 m (35 ft 9.125 in) with tip-mounted AAMs; wing area 46.00 m2 (495.16 sq ft)
Fuselage and tail: length 15.30 m (50 ft 2.375 in)
Powerplant: two SNECMA M88-3 each rated at 86.98 kN (19,555 lb st) with afterburning
Weights: maximum take-off 21500 kg (47,399 lb)
Fuel and load: internal fuel more than 5325 liters (1,407 US gal); external fuel up to one 1700-liter (449-US gal), two 2000-liter (528-US gal) and/or two 1300-liter (343-US gal) drop tanks; maximum ordnance 6000 kg (13,228 lb)
Speed: maximum level speed 'clean' at 11000 m (36,090 ft) 2125 km/h (1,147 kt; 1,321 mph)
Range: combat radius 1093 km (590 nm; 679 miles) on a low-level penetration mission with 12 250-kg (551-lb) bombs, four MICA AAMs and 4300 liters (1,136 US gal) of fuel in three drop tanks, or 1853 km (1,000 nm; 1,152 miles) on a long-range air-to-air mission with eight MICA AAMs and 6600 liters (1,742 US gal) of fuel in four drop tanks
Performance: take-off run 400 m (1,312 ft) at normal take-off weight for an air defense mission or 600 m (1,969 ft) at maximum take-off weight for an attack mission
g limits: -3.6 to +9

Above: **Trial firing of radar guided MICA from a Rafale M. Matra R550 Magic 2 short range infra-red missiles occupy the wingtip rails, while an external fuel tank is fitted to the centerline pylon.**

er, a third aircraft was flying, in the form of navalized prototype ACM 01. Ordered on 6 December 1988, M 01 was due to fly 36 months later and, most creditably, was only six days late then it took to the air at Istres on 12 December 1991. Dummy deck trials followed, undertaken in the United States.

With preparations complete, the prototype Rafale M used its 200th sortie to deploy from Istres to the deck of Foch in the Mediterranean on 19 April 1993. The first carrier launch followed the next day, using a temporarily-rigged ramp, although the vessel will be fitted eventually with a movable 1° 30' ramp which can be lowered for take-offs by other aircraft.

Soon M 02 was available, having been ordered on 4 July 1990 and flown by Eric Gerard on 8 November 1993, and both naval Rafales were landed on Foch on 27 January 1994. Their short stay ended on 4 February after light stores trials by M 01 up to two 275-Imp gal (330-US gal; 1250-liter) tanks, and servicing demonstrations by its companion. Between the two naval aircraft, B 01 had first been flown by Jean Fremond at Istres on 30 April 1993, several months behind the schedule specified when it was ordered on 19 July 1989. After a brief appearance at the Paris air show inauguration day, B 01 was fitted with RBE2 radar, as described above, and will also be used for trials of the SPECTRA self-defense system.

Desperate to replace its ageing F-8 Crusaders, the Aéronavale will be first to become operational with Rafales, accepting the first of a planned 60 aircraft in 1999 and achieving a limited IOC in 2001. These will initially be used in the air defense role only, adding air-to-surface weapons at a later date. The Armée de l'Air is expecting to receive 212 aircraft, of which the majority will be Rafale Bs. This reflects studies which suggested that a two-man crew was more effective in the air-to-ground role. The Rafale C single-seaters will have more of an air defense role. First delivery for testing is expected in 1999 with IOC hopefully being achieved in 2005.

Originally it had been planned to deliver Rafales in three baseline configurations, but now there will only be two (France and Export). The French aircraft will receive steadily improving software to add capabilities to their repertoire during the early years, initial aircraft being able only to fly air defense missions with Mica EM and Magic. Mica IR and air-to-ground modes should be available from 2002. The aircraft is in the running for several export sales, that to the United Arab Emirates offering the best possibility of success.

MiG-21 'Fishbed' Upgrades

Jon Lake

Over Vietnam, the most challenging air threat faced by US pilots was the Mikoyan Gurevich MiG-21, more normally known by its NATO ASCC reporting name - 'Fishbed'. Despite having a very limited combat radius and very basic weapons system, the MiG-21 proved hard to beat, and the US kill:loss ratio over the MiG-21 was often much lower than the Americans would have liked. In the Middle East (notwithstanding the claims of Israeli propagandists), MiG-21s chalked up many victories over Israeli Mirages and F-4s, despite the overall superiority of Israeli pilots, training and tactics.

Not a brand new aircraft even then, the MiG-21 has proved to have remarkable longevity, and large numbers remain in service. Late-model 'Fishbeds' had increased fuel capacity, more powerful radar, and superior armament, yet retained many of the more useful characteristics of the earliest members of the MiG-21 family. Thus, the MiG-21is is fast, with superb acceleration and an excellent rate of climb, is relatively agile, and presents a very small frontal radar cross-section. These features make the MiG-21 a difficult opponent in the close-in arena, even though the aircraft lacks the very slow speed/very high Alpha capabilities of the US 'teen-series' fighters and their international contemporaries. In fact, there has been little improvement in absolute performance since the 1960s, with the fighters of today being little faster (and often slower!) and featuring improvements that have been limited mainly to fuel economy and systems capability.

Above: **Photographed at the 1995 Paris air show, the MiG 'MAPO'/Sokol MiG-21-93 had won an Indian air force order for 100 upgrades the previous year. After the subsequent upgrading the Indian MiGs would be capable of between fifteen and twenty years more service.**

Above: **Small, fast and relatively agile, the MiG-21 is a classic fighter design which is suffering from poor avionics and spares parts availability. Many countries will retain the aircraft because they cannot afford to replace it with a newer aircraft.**

Close-in dogfighting capability alone is not enough for a modern fighter aircraft - as hundreds of MiG-29 pilots have discovered. That aircraft has superb handling and performance characteristics, and even enjoys a long-range pulse-Doppler radar, multi-spectral sensors and BVR missiles, yet its lack of range and of onboard data processing is a major handicap in anything but a close-in fight. If the MiG-29 fails to measure up, then the considerably less advanced and more primitively equipped MiG-21 must be judged to be severely lacking.

And yet, the provision of new avionics, systems and weapons have transformed many older fighter aircraft in countless upgrade programs across the globe, from the lightweight F-5 Freedom Fighter and Tiger to the mighty F-4 Phantom. Like its Western counterparts, the MiG-21 was an obvious candidate for high profile modernization and upgrade programs.

During the Cold War, the pressure to upgrade the MiG-21 was buried by the easy availability of new combat aircraft. Many MiG-21 customers were able to obtain MiG-23s or even MiG-29s at impossibly low prices. With the end of the Cold War, however, production of the new fighter types slumped to low levels, and prices of the new aircraft rose to realistic levels. Those nations still operating MiG-21s were faced with a dilemma - replacing the aircraft with new fighters would be impossibly expensive, yet the MiG-21 was becoming embarrassingly obsolete. The only solution was to upgrade the existing aircraft with the new capabilities required.

A number of companies identified the market opportunity and offered upgrade and modernization programs for the aircraft.

Early upgrades

Upgrading of small numbers of MiG-21s began long before the end of the Cold War, when estranged but once-staunch allies of the USSR - including Egypt and China - were faced with the need to modernize or replace their MiG-21s. Once Egypt broke with the USSR, its huge fleet of Soviet-built combat aircraft became increasingly difficult to support. China was able to help with some airframe and engine spares, but avionics and weapons were a more difficult proposition.

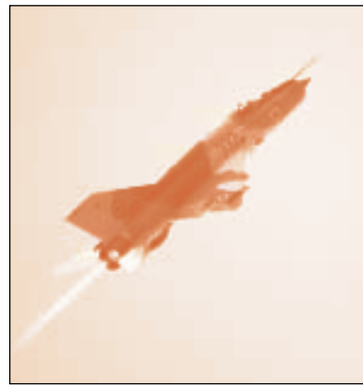
Right: **The pre-production air defense MiG-21 Lancer for the Romanian air force, 6721 (the '332' on the fuselage is a Paris air show code) sports a three tone camouflage scheme. A total of 25 air defense aircraft will be updated by Elbit for Romania.**

Replacing the entire strength of the air force was not a viable proposition, so, while some types were replaced, others, including the MiG-21, had to be retained.

After flight trials of a MiG-21 with a Smiths HUD and a Ferranti INS, a contract was placed with GEC-Marconi for the upgrade of 75-100 aircraft with a new HUD, air data computer and RWR and jammer, and with compatibility with the MATRA R.550 Magic AAM. Subsequently, these aircraft gained

AIM-9P-3 and eventually AIM-9L Sidewinders. Proposals to retrofit a new Western radar (the AN/APQ-159 of the F-5) did not bear fruit.

In China, export Chengdu F-7Ms and F-7Ps were fitted with a GEC Type 226 Skyranger ranging radar, and a Type 956 HUD/WAC (Head-Up Display/Weapons Aiming Computer) with a new radar altimeter, air data computer and other systems. Pakistan has subsequently contracted to refit its aircraft with FIAR Grifo-L multi-mode I/J-band pulse-Doppler radar, after a prolonged competition most notably against GEC Marconi's Blue Hawk. Plans for an even more radically upgraded version included AN/APG-66 radar in a new solid nose, and repositioned lateral engine intakes. This aircraft, known as the Sabre or Super 7, would also have been re-engined with an F404 or RB.199 turbofan, and was to have featured a new wide-angle HUD, increased fuel tankage, bigger wings with computer-controlled leading-edge manoeuvre devices, and other improvements. Development of the aircraft (with US partner Grumman) was abandoned following the Tiananmen Square massacre of 1989, although some elements were incorporated into the design of the Sino-Russian Chengdu FC-1 now under development.



Above and Left: **With the afterburner full on, a Romanian MiG-21 Lancer goes into a power climb. The rate of climb and acceleration of the aircraft is excellent and stems from its conception as a point defense aircraft able to intercept enemy bombers at high altitude.**

Although relatively modest, these programs did highlight the difficulties inherent in upgrading the MiG-21, and yet proved that such difficulties could be overcome. Apart from the problems intrinsic to upgrading an aircraft in the absence of co-operation from the original manufacturer, MiG-21 upgrade providers faced the difficult challenge of fitting new systems and avionics into extremely confined and unalterable spaces - such as the intake centerbody radome.

Mikoyan MiG-21-93

The major weakness of the MiG-29 and other fourth-generation Russian fighters lay in their poor cockpit ergonomics, primitive displays, lack of processing speed and capacity, and fire control system software

Center: **One of the most important modifications to all the upgrades has been in the cockpit. The pilot of this Lancer has had his workload eased by a more ergonomic cockpit layout.**

design, areas in which Russia traditionally lagged behind the West. This gave Western companies hoping to upgrade the MiG-21 greater credibility than the aircraft's own original manufacturer, which therefore became a late entrant to the field.

Not widely regarded as a producer of modern, integrated avionics and weapons systems, the Mikoyan Design Bureau and the Sokol factory in Nizhny Novgorod did enjoy some advantages over other upgrade providers. The group's status as original designers and manufacturers (the Sokol factory being better known as GAZ-21, producer of most of the MiG-21s built), gave it an unrivaled knowledge and experience of the aircraft's structure, aerodynamics and systems and avionics infrastructure, with all the necessary structural load testing and flight test data as well as the necessary jigs and tools for the building of new parts and components.

Above: **Mikoyan's upgrade has replaced the original radar with the 'Kopyo' unit, increasing detection range and giving the ability to track eight targets simultaneously.**

Right: **Most upgrades will include the provision for later generation missiles. This MiG-21-93 demonstrator has a AA-10/R-27ER 'Alamo' extended range semi-active radar AAM on the inboard pylon.**

Although it was always clear that only the later-variant MiG-21s could be viably upgraded, initial Mikoyan leaflets and brochures tended to show earlier versions, often with small spines. Under the designation MiG-21-93, the upgraded MiG-21 was fitted with a Kopyo radar, provision for advanced weapons (including fire-and-forget AAMs, and TV- and radar-guided ASMs. Most vitally, the MiG-21-93 was compatible with BVR AAMs in the form of the R-27 (AA-10 'Alamo') and R-77 (AA-12 'Adder') missiles. The aircraft also featured an increased number of chaff/flare dispensers over the wingroots, a one-piece windscreen, the MiG-29's helmet-mounted sighting system, and increased cooling capacity through use of a new ECS, based on that of the MiG-29. As time went by, and as

Mikoyan realized the scope of potential customer resistance to Russian avionics and electronics equipment, the company began to offer a number of French systems. Co-operation with French companies had begun with the MiG AT trainer program. Eventually,

the MiG-21-93 was offered with a French air data system, central computer, GPS, helmet sight, HUD, ring laser INS, and LCDs. The aircraft could also include Sherloc RWR, a Barem jammer, and even a French derivative of the Kopyo, the Thomson-Phazatron Phantom.

The Kopyo ('Lance') radar was derived from the Zhuk ('Beetle') radar developed for the MiG-29M, with a smaller planar array antenna. With a detection range of 45 km (28 miles) for a fighter-sized (3 m2/32 sq ft) target, the Kopyo had a variety of air-to-air and air-to-ground modes, and had an eight-target simultaneous tracking capability in addition to a two-target simultaneous engagement capability.

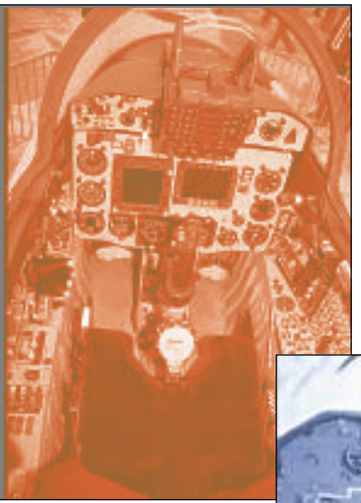
India looked far and wide for an upgrade for its MiG-21s, even approaching US companies, which proposed re-engining with the F404 turbofan and provision of the AN/APG-66 radar, as used in the F-16. In the end, though, Western solutions proved to be too expensive. Accordingly in May 1994, India placed a contract with Mikoyan and Sokol for the upgrade of 100 MiG-21is fighters to MiG-21-93 standards, although it did specify the incorporation of certain Western equipment and avionics items. They included a SAGEM INS, a Dassault Electronique EWS-A or EWS-21 RWR, and a Carapace jammer. Mikoyan offered a number of alternative engines, including the 69.65-kN (15,657-lb) TJR-25-300, a derivative of the RD-33 used by the MiG-29. India took out an option for the upgrade of 70 more aircraft, while the IAF had an eventual requirement for the upgrade of up to 250 MiG-21Ms, MiG-21MFs and MiG-21is fighters. At an estimated cost of $1.33 million, India hoped to extend the service lives of its MiG-21s to 2010-2015 or beyond.

Above: **A Radar Warning Receiver fitted to the MiG-21-93 is part of the aircraft's self defense system, utilizing chaff and flare dispensers located at the wingroot. The upgrade allows for the integration of non-Russian defensive measures and avionics .**

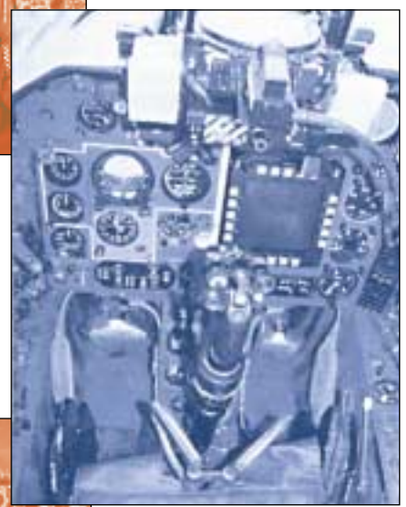
Below: **The pre-production Romanian air force close support MiG-21 Lancer seen carrying a laser guided bomb. Ten Rafael laser designator pods are also being supplied for the Lancer close support force.**

Israeli upgrades

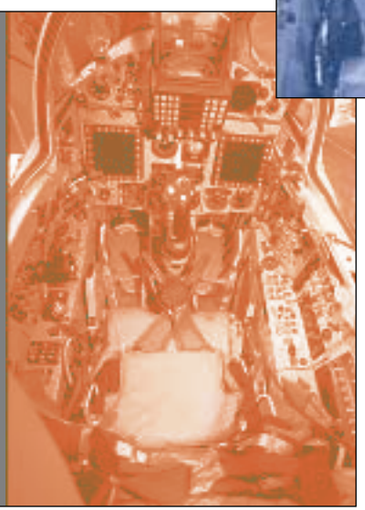
An early centre for the upgrade of previous-generation combat aircraft was Israel, where the imposition of arms embargoes had forced the tiny nation to become self-



Left: **Many dials and switches are replaced within the IAI MiG-21-2000 by two multi-functional displays. A wide angle head up display has also been fitted. Both of these improvements will increase combat effectiveness.**



Right: **The MiG-21-93 cockpit includes a French head up display (top of photograph) and a single multi-functional display.**



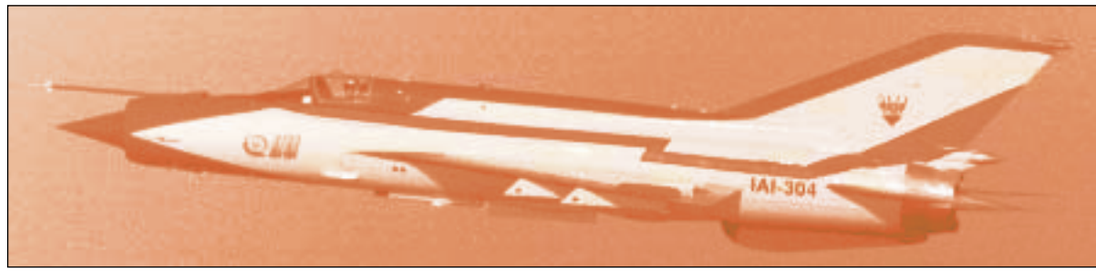
Left: **The cockpit of the MiG-21 Lancer air defense fighter has two 5 inch square multi-functional display screens in place of many analog dials. HOTAS controls have been fitted to ease cockpit workload.**

sufficient in the supply of aircraft to its air force. Israel's small aviation industry could not completely equip the force with newly-built, indigenously designed combat aircraft, however, and instead made up the shortfall by modernizing and upgrading its existing equipment. Beginning with fairly minor modifications to improve particular aspects of performance or combat survivability (e.g., IR-suppressing jet pipes for Super Mystéres and Skyhawks), the scope of such programs increased dramatically as the companies involved (principally IAI, and the electronics giant Elbit) gained experience. Soon the companies were able to offer integrated packages of modifications that encompassed structural modifications to extend aircraft life, rewiring, improved brakes and other components, new weapons and weapons hardpoints, and a new (largely indigenously Israeli) avionics system, with a modernized cockpit and an improved man-machine interface. The IDF/AF's Skyhawks and Phantoms were the first aircraft to be so comprehensively modified by IAI.

MiG-21-2000

When IAI began offering upgrades to third party nations, it initially concentrated on aircraft types that were already in Israeli service, and of which it had direct experience; principally, the McDonnell Douglas F-4 Phantom and the A-4 Skyhawk. It soon became clear that many features of the F-4 upgrade could be used to modernize other aircraft types, and IAI began looking for customers for upgrades to aircraft like the F-5. From here it was a small step to considering the MiG-21 as a potential market for the companies upgrade services. The company almost certainly had some MiG-21 experience, since the IDF/AF had test flown and evaluated a number of MiG-21s captured from its Arab neighbors.

When the Commonwealth of Independent States disintegrated, IAI watched as spares and servicing support for MiG-21s disappeared. Seeing an opportunity, IAI built up a network of suppliers from former Soviet client states and was soon able to offer any spare part or component for any late MiG-21 variant, from the MiG-21MF onwards. This was big business in itself, but also gave the company an excellent base on which to build an upgrade business for the MiG-21.



Above: **The Israeli Aircraft Industry's MiG-21-2000 demonstrator in flight. Exactly where this aircraft originated from is a bit of a mystery, but it may be one of the Cambodian air force aircraft the company is upgrading.**

IAI showed a non-flying MiG-21-2000 prototype/demonstrator (variously described as having been converted from a damaged Ethiopian MiG-21is, or from a Romanian MiG-21MF, 5902) at the 1993 Paris air show, and this aircraft was described as representing the Romanian upgrade configuration. Externally, the only major change to the aircraft lay in the provision of a one-piece wrap-round windscreen, but a sharp-eyed observer might also have noticed the headbox of a new Martin-Baker Mk 10 zero-zero ejection seat. The cockpit was entirely redesigned, with a new wide-angle El-Op HUD, and new instruments including a single small (3.5 x 4.5 in/8.9 x 11.4 cm) colour CRT HDD and a second 4.5-in square monochrome CRT display for radar presentation. The aircraft featured a repackaged Elta EL/M-2032 multi-mode pulse-Doppler radar that gave considerably greater range and flexibility than the original RP-22 Sapfir 'Jay Bird', with a detection range of about 35-45 nm (65-83 km; 40-52 miles) look-down and 35-55 nm (65-102 km; 40-63 miles) look-up, compared to the Sapfir's 11 nm (20 km; 12 miles). As an alternative to the new radar, IAI offered a lower-cost radar upgrade that bestowed improved signal processing, better data display, and direct pilot control of elevation and azimuth scan angles, while retaining the original Sapfir radar.

Other new systems included a single mission computer and a MIL STD 1553B digital databus, a new stores management system, a portable data cartridge system to allow use of a modern mission planning system, provision for laser designators, and even the Elbit DASH helmet sight. The new avionics are smaller and lighter than the systems they replaced, which allowed a 200-litre (40-Imp gal) increase in internal fuel capacity.

IAI reportedly held detailed talks with the French missile manufacturer MATRA, resulting in an agreement which allowed the Israeli company to offer the radar-guided BVR-capable Mica AAM as the long-range air-to-air weapon for its fighter upgrades, with the IR-homing Python-4 as the short-range weapon of choice for the MiG-21-2000.

IAI did obtain a contract to refurbish an initial eight of Cambodia's 19 ex-Vietnamese single-seat MiG-21s, and three two-seaters, but this was a modest upgrade, aimed principally at restoring the aircraft to airworthiness. One of the Cambodian aircraft may have doubled as the MiG-21-2000 flying prototype, which first flew on 24 May 1995. In 1996, it was revealed that IAI and Ukrainian

Above: **The pre-production close support MiG-21 Lancer was displayed at Farnborough in 1996. Both western and Russian ordnance can be carried on the Romanian upgrades.**

industrial concerns were negotiating to upgrade Ethiopia's MiG-21s, with IAI supplying and integrating the avionics, and Ukrainian factories undertaking the necessary structural airframe work.

Elbit goes it alone

Remarkably, when details of the Romanian upgrade were finalized, it was not IAI but Elbit which was contracted to upgrade the air arm's 110 selected MiG-21s. Even before IAI could display its demonstrator at the 1993 Paris Air Salon, Elbit announced that it had won the contract to upgrade the Romanian MiG-21s, although authorization to proceed was not actually given until 15 November 1993, six months after contract signature. Elbit had been a principal subcontractor in the IAI MiG-21-2000 upgrade (aimed at Romania), providing the aircraft's state-of-the-art avionics, and was selected to perform the same role in the upgrade of the Romanian aircraft, with local industry taking IAI's role of structural improvement and refurbishing, and with Elbit taking responsibility for overall program management and integration. Elbit's inclusion of local participation was probably the deciding factor in winning the contract, although the company was one of five (the others being IAI, MAPO-MiG, GEC and Thomson-CSF) which responded to the Romanian tender document issued in 1992.

The $300 million contract covered the upgrade of 75 single-seat aircraft for use in the close air support role, and 25 for use in the air defense role, plus 10 two-seat trainers. All aircraft are stripped down, and fully overhauled and rectified as necessary, this process equating to a virtual remanufacture. The aircraft's systems and retained avionics are similarly refurbished by Aerostar. The Romanian company has extensive experience in maintaining and refurbishing the MiG-21 and is a source of spare parts which are no longer available from Russia.

All aircraft have an entirely new avionics system, designed around dual MIL STD 1553B digital databuses, driven by a single Modular Multi-Role Computer. The cockpit of the Lancer is entirely redesigned with full HOTAS control of all mission-critical systems and the main panel is tidied through the addition of two 5-in (12.7-cm) square multifunction display screens, retaining only a handful of standby/back-up analog instruments. The right-hand display screen is fitted only to the air defense aircraft (and to the front cockpits of the trainers, prototypes and early production aircraft), and is a monochrome display used for displaying radar information. The left-hand display is a colour display and is used primarily as a tactical situation display. The aircraft has an off-the-shelf EI-Op HUD, with an up-front control panel, and provision is made for the DASH helmet sight.

For combat survivability the aircraft is fitted with an Elisra SPS-20 RWR, with forward hemisphere antennas on the upper sides of the nose and rear hemisphere antennas on the top of the fin. The aircraft has provision for an active jammer to be carried, and IMI 30-round chaff/flare dispensers are fitted on each side of the base of the ventral fin.

The Lancer has a new built-in test system and a colour video camera for recording HUD data. The program provides an advanced training system with an ACMI-type debriefing facility, while a mission planner and associated data transfer modules are also supplied. The aircraft have a new Hybrid Navigation System (HNS), with a GPS-corrected Litton-Italiana LISA 4000 strapdown INS, and use COTS (Commercial Off-The-Shelf) Allied Signal/Bendix VOR, ILS and DME.

The close air support aircraft and the trainers have their existing radar replaced by an Elta EL/M-2001-B ranging radar, but this is simple to fit and to integrate, and can even use the existing radome. The 25 air defense-configured aircraft have an Elta EL/M-2032 multimode pulse-Doppler radar requiring a new radome, and may lack the new radar altimeter fitted to the close air support aircraft and trainers, but the aircraft are otherwise identical.

The prototype (9809, a close air support-configured aircraft) flew on 23 August 1995, two months ahead of schedule. The first trainer (327, a MiG-21UM) flew on 8 May 1996. The first pre-production close air support aircraft (714) was ready in time for participation at the 1996 Farnborough air show, and a pre-production air defense aircraft (6721, in three-tone grey air superiority camouflage) appeared at the Paris Air Salon at Le Bourget in June 1997. The modernized aircraft has been dubbed Lancer.

The Lancer is compatible with a wide range of weapons of both Western and Soviet origin. To enable this to be accomplished most easily, a new pylon with a common forward suspension lug and two rear lugs (one for NATO standard weapons, one for Soviet) was designed and developed, and fitted with a multiple release unit. Romania ordered 'several hundred' MATRA Magic 2 IR-homing AAMs to equip its newly upgraded MiG-21s, a surprising choice in view of the fact that the superb R-73 (AA-11 'Archer') was already in the inventory for Romania's MiG-29s, and in view of the easier integration promised by an Israeli missile, perhaps Python-3 or Python-4.

For the tactical reconnaissance role Elbit have designed an all-new reconnaissance pod, with a forward-facing oblique camera

Right: **Surrounded by the latest ordnance, the MiG-21-93 upgrade will provide the Indian air force with an effective weapon far removed from the original mid-1950s aircraft.**

SPECIFICATION

Mikoyan-Gurevich MiG-21 Upgrades

Wing: span 7.154 m (23 ft 5.7 in); aspect ratio 2.23; area 23 m2 (247.5 sq ft)
Fuselage and tail: length 15.76 m (51 ft 8.5 in) including probe; length 12,285 m (40ft 3.9 in) excluding probe and centerbody; height 4.125 m (13 ft 6.2 in); wheel track 2.787 m (9 ft 1.75 in); wheel base 4.71 m (15 ft 5.5 in)
Powerplant: one MNPK 'Soyuz' (Tumanskii) R-25-300 turbojet rated at 40.2 kN (9,038 lb st) dry and 69.65 kN (15,653 lb st) with afterburning, with an emergency regime rating of 97.12 kN (21,825 lb st) above Mach 1 and at heights up to 4000 m (13,123 ft) for periods of up to three minutes. Provision for two 24.52-kN (5,511-lb st) SPRD-99 solid rocket boosters
Weights: empty 5450 kg (12,015 lb); normal take-off 8725 kg (19,235 lb); maximum take-off 9800 kg (21,605 lb) or 8800 kg (19,400 lb) on rough strip, or 10400 kg (22,928 lb) with KT-92D wheels and 058 tyres
Fuel and load: internal fuel 2880 litres (760 US gal); external fuel up to 1750 liters (462 US gal) in three drop tanks; maximum ordnance 2000 kg (4,409 lb)
Speed: maximum level speed 'clean' at 13000 m (42,650 ft) 2175 km/h (1,177 kt; 1,351.5 mph)
Range: 1470 km (795 nm, 913 miles) at 10000m (32,800 ft) with one 800-liter (211-US gal) drop tank
Performance: maximum rate of climb at sea level with two missiles and 50 per cent fuel more than 13800 m (45,275 ft) per minute; service ceiling 17500 m (57,415 ft); take-off run 830 m (2,720 ft); landing run 550 m (1,800 ft) at normal landing weight with SPS and brake chute

and a vertical survey camera, and with additional space for other sensors to be added at a later date. The Lancer will also carry the Rafael laser designator.

Future for the upgrades

There are a number of other potential upgrade providers for the MiG-21, most notably TEREM in Bulgaria. TEREM, already highly experienced in MiG-21 overhaul, repair and modernization work for the Bulgarian air force and some Soviet client states, was formally licensed to upgrade MiG-21s by Mikoyan in 1994. The Bulgarian company immediately upgraded six MiG-21s of different versions as demonstrators. With its high engineering standards and low labor costs, TEREM is considered by Mikoyan to be an ideal partner for its own upgrade, and has been spoken of as a potential upgrade provider for Syrian and Indian MiG-21s.

The number of MiG-21s upgraded has not been enormous. With the drawdowns in defenses following the end of the Cold War, many operators have chosen to retire rather than upgrade their MiG-21s. From the early 1990s, MiG-21s became museum pieces and privately owned jet warbirds in their original form, and others have been converted to serve as unmanned target drones. Thus, not all of the MiG-21s remaining in service are realistic upgrade prospects.

During the 1980s, the Western fighter pilot could safely assume that any MiG-21 he encountered would be equipped with only the most rudimentary fire control radar, that it would have no BVR armament, and would almost certainly be wholly reliant on GCI control. All of these weaknesses have been addressed in the available upgrade packages. Today, therefore, if a hostile aircraft can be identified as a MiG-21, it may be much more than a primitive 1950s vintage fast jet. It could represent a real and potent threat, with a long reach and a deadly punch. Some upgraded MiG-21s probably offer a more dangerous threat than early generation F-16s or MiG-29s. The aircraft's small size does make it likely that it will have a relatively small radius of action, and the limited wingspan makes it unlikely that the aircraft will have more than six hardpoints available for AAMs, even if wingtip stations have been provided. Nevertheless, there is certainly no room for complacency.

Boeing E-3 Sentry

René J. Francillon & & David Willis

Since its introduction into operational service, the distinctive E-3 Sentry has proved itself time and again to be an invaluable component in the USAF and NATO air defense systems, locating and tracking enemy intruders and directing friendly interceptors to their quarry.

At the end of World War II aircraft began to carry large surveillance radar. Unlike previous airborne radar, these were designed to search vast volumes of sky and detect every aircraft present. The most widely used of the early generation of AEW 'picket' aircraft was the Lockheed EC-121 Warning Star, a series based on the Super Constellation airliner. These did a great job and served from the early 1950s until after the Vietnam War, but they had several limitations.

One limitation was that, being a piston engined aircraft, the EC-121 had quite modest performance, and it could not climb very high. The higher an observer is the farther he can see. Walking on the beach, the horizon at sea is about 3.2 km (2 miles) away. From a tall seaside hotel one might see 16 km (10 miles). An EC-121 might 'see' 240km (150 miles). In the 1960s the US Air Force calculated that a radar in a big jet aircraft at 30,000 ft (9145 M) would 'see' 395 km (245 miles). Obviously, the farther one can see

Above: **Based on the airframe of the Boeing 707 airliner, the E-3 Sentry was a quantum leap over the aircraft it replaced when it entered service with the USAF. The large 'rotodome' also makes it one of the easiest aircraft to recognize.**

Boeing E-3 Sentry

the better: it brings in a greater number of targets, and it increases the warning time of an enemy attack.

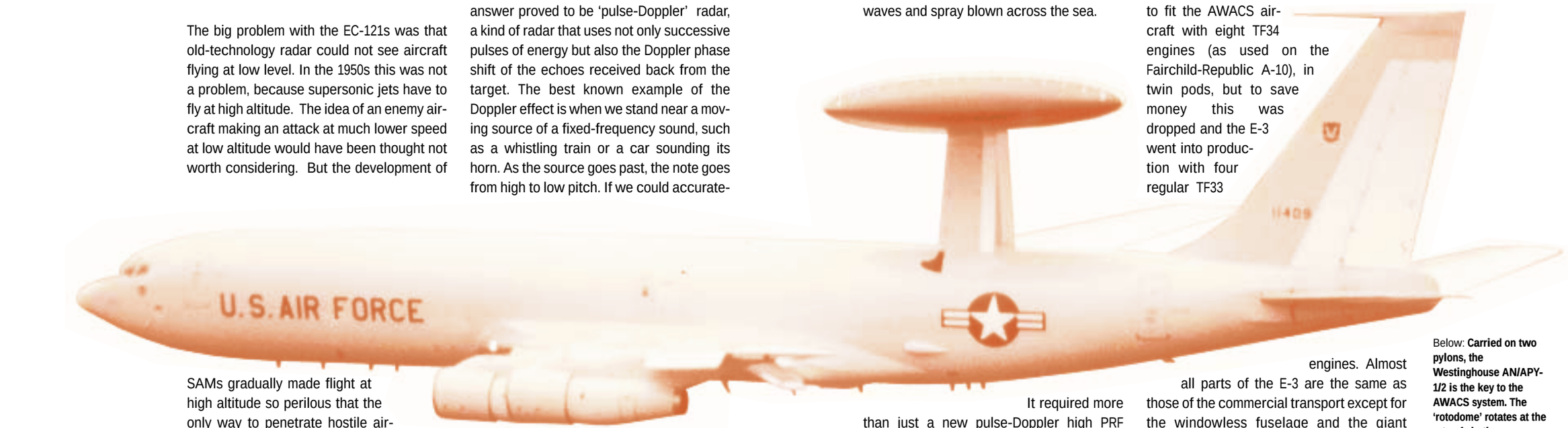
The big problem with the EC-121s was that old-technology radar could not see aircraft flying at low level. In the 1950s this was not a problem, because supersonic jets have to fly at high altitude. The idea of an enemy aircraft making an attack at much lower speed at low altitude would have been thought not worth considering. But the development of SAMs gradually made flight at high altitude so perilous that the only way to penetrate hostile airspace has ever since been at the lowest height possible, to stay down out of the line of sight of a high-flying aircraft. This is because the tiny picture of the enemy aircraft on the radar screen was swamped by the giant reflection of the radar signals from the ground, just beneath the aircraft.

Above: **One of NATO's aircraft in flight. Prominent on the tail is the Grand Duchy of Luxembourg coat of arms, where the aircraft are registered. They are based at Geilenkirchen in Germany.**

Radar Design

In 1965 the US Air Force began its ORT (Overland Radar Technology) program to try to find out how to make a radar that could look down over land and see small jets speeding at so called treetop height. The answer proved to be 'pulse-Doppler' radar, a kind of radar that uses not only successive pulses of energy but also the Doppler phase shift of the echoes received back from the target. The best known example of the Doppler effect is when we stand near a moving source of a fixed-frequency sound, such as a whistling train or a car sounding its horn. As the source goes past, the note goes from high to low pitch. If we could accurately measure the difference between the high pitch of the oncoming sound and the low pitch of the receding sound we could work out the speed of the vehicle.

The pulse Doppler radar works by comparing the pitch (or PRF) of the radar signal sent out with the PRF of the echoes received back. Most signals will be received back from the ground, and here the difference in PRF is due to the speed of one's own aircraft. All other PRFs come from targets moving relative to the ground, and they show up clearly. Even so there are plenty of problems. There are certain target angles and ranges where either the target cannot be seen or the apparent range may be half or twice (or four times) the true value. A lot of research was needed to get an overland downlook radar that really worked. Even then it suffered from such problems as the false 'velocities' of leaves agitated by wind, or waves and spray blown across the sea.



It required more than just a new pulse-Doppler high PRF radar, able to send out signals at high and low PRFs together, in order to sort out the true target ranges from the false ones. It also needed a very powerful and fast computer, to check each one of the billions of radar pulses and echoes and to display on the operators screens only the real targets and the real target speeds and distances, Even then there are still problems. How can the radar tell whether a target at very low level moving at 87 kts (160 km/h; 100 mph) relative to the ground is a Soviet helicopter bristling with weapons or a harmless BMW on the autobahn ?

Westinghouse AN/APY-2

The winner of the overland downlook radar was Westinghouse. There was a study of purpose designed carrier aircraft, but these could not do much better than the existing Boeing 707-320 airliner. To increase endurance on station it was planned in 1969 to fit the AWACS aircraft with eight TF34 engines (as used on the Fairchild-Republic A-10), in twin pods, but to save money this was dropped and the E-3 went into production with four regular TF33 engines. Almost all parts of the E-3 are the same as those of the commercial transport except for the windowless fuselage and the giant 'rotodome' mounted on a braced pylon above the rear fuselage.

Below: **Carried on two pylons, the Westinghouse AN/APY-1/2 is the key to the AWACS system. The 'rotodome' rotates at the rate of six times per minute, giving 360 degree coverage.**

The heart of the AWACS detection system is its Westinghouse AN/APY-2 Overland

Boeing E-3 Sentry

Above: **Winner of the Airborne Warning & Control System (AWACS) requirement, two EC-137Ds were built as prototypes for the E-3 series, 71-1407 being the firstof these. Both EC-137Ds were later redesignated E-3As.**

Downlook Radar (ODR) which, with other sensors and instrumentation, is mounted in a saucer-like rotodome mounted on two 3.35-m (11-ft) struts above the rear fuselage. The AN/APY-2 replaced the AN/APY-1 system from the 25th aircraft onwards and is fitted to all export E-3s. The deep circular rotodome is some 9.14 m (30 ft) in diameter, weighs 1540 kg (3,395 lb) and is canted 2.5° downward. In operation, the dome rotates six times per minute. The radar is capable of tracking up to 600 low-flying aircraft. On the back of this vast antenna is mounted a mass of auxiliary equipment inside a large structural beam giving ample strength to resist distortion that would harm accuracy. On the back of this beam is a communications and digital data-link antenna which is used for IFF purposes and for secure communications with perhaps hundreds of other friendly stations such as ground headquarters, ships at sea and other aircraft. The rotodome is completed by adding a liquid cooling system and then streamlining everything inside front and rear radomes of glass-fibre sandwich to form a shape like a giant flattened egg. This has only a minor effect on aircraft speed and handling.

Above: **Currently 17 Sentrys are operated and owned jointly by (most of) the member states of NATO. Few NATO countries could afford to operate the AWACS system individually.**

Internal Systems

In operation the radar is extremely complex, but basic principles are straightforward. The antennas are mounted on large bearing pivots, and these rotate at 0.25 rpm (1.5 degrees per second) to keep the bearings lubricated. When the radar is in operation the rotodome speeds up to 6 rpm (36 degrees per second) to keep the colossal radar beam sweeping round to all points of the compass. In the first 24 E-3s, designated Core E-3As, an IBM CC-1 computers processes the incoming radar echoes at the rate of 740,000 per second and feeds the results to nine SDCs (Situation Display Consoles) and two ADUs (Auxiliary Display Units). The consoles are arranged in rows of three across the cabin above the leading edge of the wing. Immediately behind them is the station for the Duty Officer. Up front are the flight crew, masses of electronics (concerned mainly with navigation and communications) and the station for the computer operator. Further aft is the console for the radar maintenance officer, and right at the tail end is a large gallery and crew rest area. On a typical mission, an E-3, which has an unrefueled endurance of 11 hours, routinely refuels and stays aloft for up to 18 hours, carrying a crew of 20 including 16 mission specialists such as weapon controllers, radar operators and communications specialists.

Once on station the radar is brought to full power and operated in any of six modes. Simplest is Passive, in which no signals are emitted; instead the rotating antennas receive every kind of electronic signal (from air, sea and land sources) and the on-board equipment can pinpoint their position and analyze their characteristics to identify the sources. In the BTH (Beyond The Horizon) mode, all radar power is put into achieving range, without elevation data, for full-range detection to beyond the visible horizon (limits are classified). The commonest mode is PDES (Pulse-Doppler Elevation Scan) in which the main beam is electronically swept up and down to cover the whole surveillance airspace. The received signals, of which there may be many hundreds, are analyzed to determine the exact peak signal (echo) strength, which in turn gives target elevation. At all times target direction is read off by applying a small time of flight correction to the direction in which the antenna is pointing. PDES provides the maximum information and suffers the greatest loss in range. Where detection of distant targets is more important than knowing their height it is possible to switch to PDNES (Pulse-Doppler Non-Elevation Scan), in which the vertical scanning is eliminated. The sixth operating mode is Interleaved, which means that various high PRF and low-PRF modes are sent out together in order to provide the best combination of signals thereby optimizing the crews' ability to carry out the long-range detection of both aircraft and ship targets beyond visual range (BVR).

Below Left: **After the failure of the Nimrod AEW aircraft, the RAF ordered seven E-3D Sentry AEW. Mk 1s. The last produced, ZH107, was the last 707 airframe built.**

Left: **The communications console in the Sentry. Vast amounts of data are acquired during missions, which must be quickly coded and sent to interested parties.**

Above: **A pre-delivery shot of three USAF E-3s on the Boeing ramp. The USAF is the major user of the type receiving a total of 34, including two prototypes designated EC-137D.**

Above: **As all USAF E-3s are powered by the Pratt & Whitney TF-33 turbofan, this aircraft using CFM56s, is a Saudi Arabian aircraft in US marks for its delivery flight. The Saudis operate five Sentrys.**

SPECIFICATION

Boeing E-3C Sentry

Powerplant: four Pratt & Whitney TF33-P-100/100A turbofans each rated at 93.41 kN (21,000 lb st)

Dimensions: wing span 145 ft 9 in (44.42 m); length 46.61 m (152 ft 11 in); height 12.73 m (41 ft 9 in); wing area 283.35 m2 (3,050.00 sq ft)

Weights: operating empty 77996 kg (171,950 lb); maximum take-off 147420 kg (325,000 lb)

Performance: maximum level speed at high altitude 853 km/h (530 mph; 460 kt); operating ceiling 8840 m (29,000 ft); operational radius 1612 km (1,002 miles; 870 nm) for a 6-hour patrol without flight refuelling; endurance more than 11 hours without flight refueling

Right: **A RAF Sentry crew member monitors one of the situation display consoles. With missions lasting upto 10 hours crew members require frequent breaks, for which bunks and a galley are located at the rear of the aircraft.**

History

The Boeing E-3 Sentry is the West's principal AWACS (airborne warning and control system) platform. Using the airframe of a Boeing 707-320 airliner and a massive payload of radar and electronic sensors, the E-3/AWACS is a flying headquarters for C3I (command, control, communications and intelligence), employed near a combat zone to monitor aircraft and missiles and to direct friendly warplanes.

The EC-137D prototype for the AWACS series first flew on 5 February 1972. The first E-3A Sentry, of a total of 34 (including two EC-137Ds) procured by the USAF, made its maiden flight on 31 October 1975, and following completion of full-scale development in 1976, the first operational example was delivered to the 552nd AC&CW at Tinker AFB, OK, in March 1977. IOC (initial operating capability) was gained in April 1978 and E-3s assumed a US continental air defense role in January 1979. Since then, AWACS aircraft have been involved globally in all American combat operations in Grenada (1983), Lebanon (1983), Panama (1989) and Iraq (1991).

USAF/NATO

Twenty-two E-3A and two EC-137D aeroplanes, collectively termed 'core' aircraft when they were standardized in the late 1970s, were upgraded to E-3B standard. The first was converted by Boeing, the rest by the air force at Tinker AFB using Boeing-supplied kits. Block 20 improvements include faster IBM CC-2 computer, ECM-resistant communications, a modest maritime surveillance capability, additional radios, five more display consoles and provision for Have Quick secure communications. The 522nd AW&CW took delivery of the first E-3B in July 1984. Under Project Snappy in 1991, 15 E-3Bs were fitted with an additional (and so far unidentified) sensor for operation Desert Storm.

In 1984, 10 E-3As were modified to E-3C standard with slightly larger crew capacity, five additional consoles and radios and Have Quick communications equipment. All but the first 25 E-3 airframes have inboard underwing hardpoints. Eighteen E-3A 'standards' were delivered to NATO, which also uses three Boeing 707TCAs for training.

Boeing E-3 Sentry

Above: **The USAF Sentrys have seen continuous improvement to the radar system and electronics, vastly altering the insides but producing few noticable external differences.**

Dornier at Oberpfaffenhoffen integrated the systems of NATO Sentries, which were then sent to Nos 1, 2 and 3 Squadrons of the E-3A component, NATO Airborne Early Warning Force at Geilenkirchen, Germany.

The USAF is pursuing a multi-stage improvement program to upgrade E-3B/C aircraft with JTIDS (Joint Tactical Information Distribution System) for digital communications, Quick Look ESM system to detect signals from hostile targets, and GPS navigation. A JE-3C temporary test aircraft (73-1674) was bailed to Boeing on receipt of a contract to develop and integrate the AN/AYR-1 ESM system on USAF and NATO E-3s. This is mounted in canoe shaped fairings on the sides of the nose. A second system was installed on a NATO E-3A and redelivered in October 1991.

Exports

In addition to USAF and NATO aircraft, the E-3 has also been exported to three countries. E-3A 'standard' (as distinguished from 'core') versions have been delivered to Saudi Arabia (five), the Saudis having also acquired KE-3A tankers. Following the cancellation of the ill-fated Nimrod AEW aircraft for the Royal Air Force, the UK government placed a contract for six aircraft designated E-3D Sentry AEW.Mk 1 in December 1986.

An option on a seventh aircraft was converted in October 1987. At approximately the same time, the Armée de l'Air placed an order in February 1987 for three E-3F SDAs (Système de Détection Aéroportée). An order for a fourth aircraft was added later, but options on a further two E-3s were dropped in 1988. Both European versions differ markedly from other E-3s, with Boeing giving each nation a 130 per cent industrial offset. The primary difference is the replacement of TF33 turbofans with 106.8-kN (24,000-lb st) CFM56-2A-3 turbofans, and installation of an upper forward fuselage-mounted SOGERMA inflight-refuelling probe in addition to the refuelling receptacle. RAF aircraft also have wingtip-mounted Loral

Above: **With the exception of equipment changes and modifications, the E-3 Sentry's cockpit is basically that of the Boeing 707. Located directly behind the pilot and co-pilot is the flight engineer's station .**

Above: **Sentrys are high-value targets. Flying orbital flight paths and carrying high powered radar they are easy to locate and even the two missile carrying pylons on later aircraft would give them little chance against fighters or long range SAMs.**

1017 'Yellow Gate' ESM pods. The RAF's first E-3D (ZH101) was first flown on 11 September 1989, and made its initial flight in fully-equipped mode in 5 January 1990. It preceded the French E-3F which first flew on 27 June 1990. The last RAF aircraft was the ultimate Boeing 707 airframe produced, after which the production line was closed, forcing Japan to opt for an AEW version of the much newer twin-engined Boeing 767, using essentially E-3C equipment. Planned improvements for the E-3 include the Block 30/35 program with radar improvements, an upgrade of JTIDS to TADIL-J standards, improved memory and compatibility with GPS. A further improvement may be funded, which will give a radar upgrade for USAF aircraft, with new processors and displays and pulse compression for enhanced performance against small targets.

A General Introduction to Modern Air Combat

Jon Lake

Above: **Modern combat aircraft perform a large number of varied missions, requiring airborne ordnance covering a wide range of tasks and capabilities. Displayed in front of this Swedish air force Viggen is a range of bombs, rocket pods, missiles and fuel tanks.**

Air-to-air missions and weapons

The advent of the military aircraft (which initially operated in the reconnaissance role) brought with it an immediate need for effective countermeasures. Thus the fighter was born - an aircraft designed to shoot down other aircraft in air-to-air combat. It rapidly became clear that shooting down enemy aircraft willy-nilly, while useful, was less effective than doing so as part of a campaign to gain control over the air in a particular area.

Today, air-to-air combat is still viewed as an integral part of the counter-air campaign, which aims to achieve and maintain a degree of control over a particular portion of airspace. Control of the air is of crucial importance for the effective conduct of land and sea operations, as well as air operations. Control of the air prevents the enemy from using air power effectively, while allowing allied air power efforts to be more efficient. This makes the counter-air campaign of pivotal importance for success in any military operation.

While it is obviously desirable to have complete control of the air (dominance, known

Weapon Systems

Above: **A test firing of a Matra Super 530 missile from a French air force Mirage F1.**

Right: **Under a pylon of a Mirage 2000, the Matra R550 Magic is a French short range infra-red air to air missile designed to compete with the American Sidewinder in the market place. Any aircraft that can use the Sidewinder can use the Magic, due to common interface design.**

Above: **One of the earliest air to surface missiles, the Bullpup was built in several versions (clockwise from the left, AGM-12B, AGM-12C, AGM-12D and training round ATM-12A).**

attack aircraft, including the suppression of enemy air defenses, attacks against the enemy's command and control network and attacks against enemy airfields. Forming part of the same campaign, fighter operations are generally discrete. Although there are genuinely multi-role aircraft, few examples of those aircraft perform air-to-air and air-to-ground operations simultaneously, except occasionally when flying 'self-escorted' attack missions.

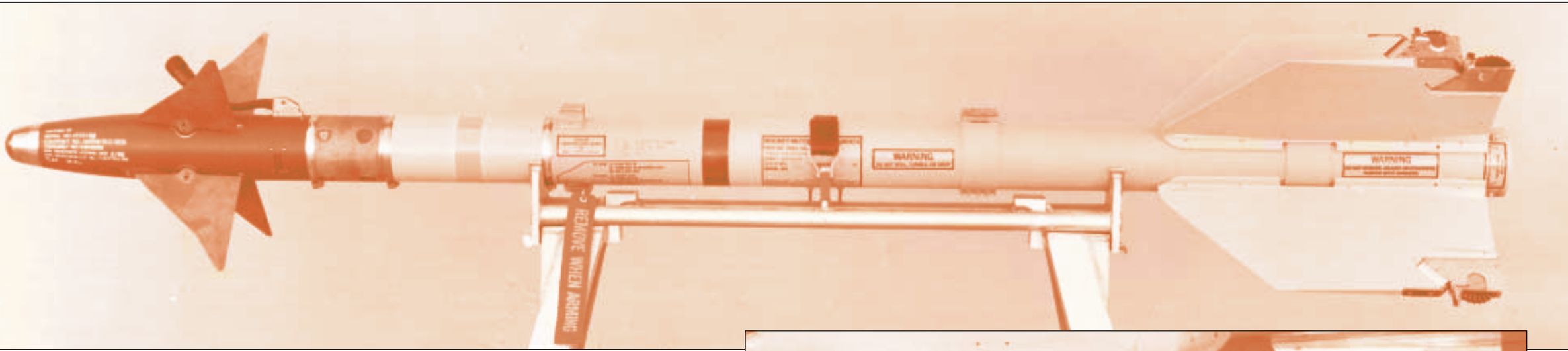
Generally speaking, counter-air operations can be split into defensive and offensive components. Defensive counter-air operations aim to maximize enemy losses while minimizing damage to friendly forces and facilities. The priority will normally be given to intercepting enemy aircraft before they can attack their targets, though shooting down an outbound enemy aircraft will prevent that aircraft being a player in any subsequent attacks. The classic defensive counter-air campaign is represented by the RAF in the Battle of Britain. Defensive counter-air operations will always be necessary, in peace or war, to guard against surprise attack. They may be the only form of operation available to a force commander, and have certain advantages, since they are inevitably conducted over friendly territory, closer to friendly airfields than to those of the enemy, allowing the defender to generate a higher sortie rate. Political constraints or the effectiveness of enemy air defenses may even preclude offensive action, or may be necessary to weaken the enemy before offensive operations are attempted. Enemy airfields may even be out of range.

Manned fighters will generally provide only one element of a layered and fully integrated

as air supremacy), lower levels of advantage may be acceptable. Air supremacy renders the enemy incapable of interference, at all. Air superiority, however, allows friendly operations to be undertaken at any given time and place without prohibitive interference by enemy air power. A still-lower level of advantage is a 'favorable air situation' under which enemy air operations cannot prejudice the success of friendly operations. Even in a generally hostile air situation, any of these states of advantage may be obtained locally or for a limited duration, in support of specific operations.

Counter-air operations include some missions flown by friendly fighter-bombers and

Weapon Systems



Above: **This Sidewinder is representative of the third generation AIM-9L or 'M models introduced in 1976 and 1982. Continued development of the basic missile has seen improvements in the warhead, homer, an increased aspect engagement profile and a better ability to deal with countermeasures.**

air defense system, which will be designed to inflict progressive attrition on an incoming attacking force. This will consist of a detection system (usually relying primarily on radar), with a command and control system responding to the threat and co-ordinating the defensive response. Finally, there will be a weapons system to engage the enemy, usually consisting of some mix of fighters and SAMs, perhaps with AAA for short-range point defense.

Fighters are the most flexible and versatile element in the air defense system, since they can be switched to other tasks, can identify targets before engaging them, and may be easily redeployed to face a specific threat axis. This allows them to provide air defenses for relatively large areas, which would be prohibitively expensive using SAMs, which are better for defending limited geographic areas or borders. The fighters' limitations include a relatively short range and endurance, short sensor range and a longer response time than SAMs. These limitations can be addressed through the effective use of inflight refueling and airborne early warning radar platforms, and by linking fighters to each other, to ground stations and AEW aircraft using secure datalinks. Fighters may also be maintained on airborne standby, flying a combat air patrol (CAP) in the path of the anticipated threat. If more advanced warning can be expected, fighters may be scrambled from ground alert.

Defensive counter-air operations will generally be undertaken by dedicated interceptors, scrambled from a high state of readiness or diverted from a standing CAP. The aim will usually be to detect and engage the enemy as far from the target as is possible, classically accelerating to high supersonic speed to launch BVR missiles at the incoming raid, before they can launch their own BVR missiles or stand-off air-to-ground weapons. Long range and endurance, the ability to operate by day and night in all weathers and the ability to carry multiple weapons are more important to the interceptor than absolute performance and agility. Interceptors will usually be two-seaters, with a dedicated backseater to operate the powerful onboard sensors and to reduce pilot workload in poor weather conditions. Aircraft like the Tornado F.Mk 3 and F-14 represent the optimized interceptor.

Carrying the counter-air campaign to the enemy may have some advantages. Offensive counter-air missions allow the attacker to seize the initiative and concentrate his efforts against an enemy area of weakness. It also denies the enemy any respite or sanctuary. When attacking an enemy's air defenses, some elements of the campaign (SEAD and airfield attacks) will be conducted by attack aircraft, and they are best considered elsewhere. Pure air-to-air fighters do have a role to play, conducting sweeps and escorting friendly attack, reconnaissance or EW aircraft. The coalition air campaign during Operation Desert Storm, or the Israeli operation over the Beka'a in 1982 was a classic example of the offensive counter-air campaign. Offensive counter-air operations usually accompany

Above: **A fourth generation Russian short range air to air missile, the AA-11/R-73 'Archer' is thought to have entered service with the Russia services in 1987. The nose of the missile displays small incidence sensors, fixed fins and moving control fins.**

Weapon Systems

air-to-surface operations but may be mounted independently - perhaps over enemy-held territory. Offensive counter-air operations may be accompanied by surface action, by special forces or even by artillery if enemy targets are within range.

When fighter sweeps are mounted in conjunction with attack operations, the attack aircraft tend to draw enemy fighters into the air, where they are engaged by the friendly fighters. As they do so, they clear the way for the attack aircraft to go on to their targets. Sweeps may be conducted to establish local air superiority in a given area, or more narrowly to cover the planned route to be used by attack aircraft. Fighters could also operate in the escort role, accompanying or screening the attack force. Aircraft used in offensive counter-air operations must have sufficient range to reach the target area, but the ability to outfight hostile fighters when they get there is crucial. The offensive counter-air role may be undertaken by dedicated fighters (like the F-15C) or by multi-role tactical fighters like the F/A-18 Hornet.

Offensive counter-air aircraft must have a range of close-range and BVR weapons, with autonomous sensors and good performance and agility.

Although the fighter pilot might like to view himself as the modern counterpart of a medieval knight, engaging the enemy in single combat, the truth is less glamorous. Rather than aiming to meet the opponent on even terms in a chivalrous duel, letting skill alone decide the outcome, the modern fighter pilot will stack the odds in his favor. His aim should be to sneak up on his opponent undetected and to kill the enemy before he even knows he is under attack, using more effective weapons and sensors, and numerical superiority if at all possible. Even in World War I, fighter pilots were not the 'knights of the air' often depicted. The most successful were those who shunned combat except when circumstances were most favorable, and who preferred to stalk the enemy and remain unseen as they delivered their deadly blow. Of course, the first shot may be unsuccessful, or rules of engagement may require the fighter pilot to close with the target to visually identify the enemy. But as soon as he has to close with the enemy, air combat becomes more unpredictable and more dangerous. Does the enemy have a wingman who can not be seen, and who may be about to turn the tables? Does the enemy have better close-in armament than the attacker? There is no place for sportsmanship or chivalry in air combat - the aim is to do maximum damage while exposing oneself to minimum risk.

Above: **The short range Python 3 developed in Israel is an all aspect infra-red air-air missile. Credited with 50 kills in the Beka'a Valley in 1982, the Python 3 is fitted with an 11 kg high-explosive fragmentation warhead.**

Since the late 1950s, the primary fighter weapon has been the guided air-to-air missile, which has largely supplanted the gun, and which has entirely replaced the use of barrages of unguided air-to-air rockets, favored briefly as an anti-bomber weapon during the 1950s. Even more briefly, before the development of precise missile-guidance systems, nuclear-tipped unguided missiles were deployed as a means of combating inbound formations of bombers. The air-to-air missile is often portrayed as a

Above: **The medium range, radar-guided, air to air AMRAAM on a Sea Harrier FA Mk 2. Designed to replace the the AIM-7 Sparrow, the AMRAAM is in service with 15 countries.**

Left: **Over 200,000 Sidewinder missiles have been built and carried on a large number of aircraft, from AH-1 HueyCobras attack helicopters to the Nimrod maritime reconnaissance aircraft. This F-15 Eagle carries AIM-9Ls.**

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Above: **The prototype AIM-120 AMRAAM is lowered by a Hughes Missile Systems technician. In the background are other products of the company, the long range AIM-54 Phoenix carried by the F-14 Tomcat and the AGM-65 Maverick air-to-surface missile.**

wonder weapon, which, once launched, will always find and destroy its target. In fact, a successful missile launch can be difficult to achieve, and there is only a very limited envelope in which countermeasures, defensive maneuvring and other factors will not have a high chance of spoiling the shot. No missile is foolproof.

In general, IR-homing AAMs are used for close-range engagements (within a couple of miles) and are extremely fast and agile. They are designed to close on the IR energy produced by the hot jet-pipe of an enemy aircraft, but often incorporate sophisticated algorithms which can aim the missile ahead of the jetpipe, to be adjacent to the cockpit and vulnerable areas of the fuselage, including the fuel tanks. Such weapons can sometimes be decoyed by using intensely burning flares, or even by flying across the sun, although modern IR-homing missiles may be able to discriminate between genuine target IR energy and other types. Even with helmet-mounted sights or other devices to allow an off-boresight shot, an IR-homing AAM is best fired straight ahead from directly in front of or directly astern the target, giving it the best chance of following a turning target. Making the missile turn hard on launch uses up limited energy and control power, dramatically reducing overall range.

At longer ranges (often beyond visual range - BVR) the weapon of choice tends to be radar-guided, usually homing onto radar energy transmitted by the launch aircraft and reflected by the target. Such guidance is known as semi-active radar homing. Such a semi-active radar homing missile requires that the pilot of the launch aircraft maneuvres to keep the target within the 'cone' of his radar. He will then have to keep the target 'illuminated', rendering himself vulnerable to passive-radar homing missiles. If the enemy pilot can manoeuvre out of the cone, he will escape. Active radar-homing missiles have a fire-and-forget capability, but small antenna size gives limited range, and active radar is usually limited to terminal homing in the final phase of the missile's flight, with mid-course guidance by INS or semi-active radar homing. Active radar homing missiles may, in any case, be decoyed by chaff or enhanced-signature decoys, or by jamming.
Today, the gun is little more than a last-ditch weapon, useful for firing warning shots during an intercept, or where rules of engagement preclude the use of missiles. The gun should not be used from choice when the pilot has 'run out of missiles'; that is the time to return to base and reload! Nonetheless, the gun can be useful, and the days of the late 1950s, when a generation of fighters was designed and built without an internal gun, have more than likely gone forever. Developments in aircraft guns (perhaps including the incorporation of 'smart bullets') may improve range performance and accuracy, and the emergence of highly-constrained peacekeeping-type operations may lead to a resurgence in the importance of the humble gun.

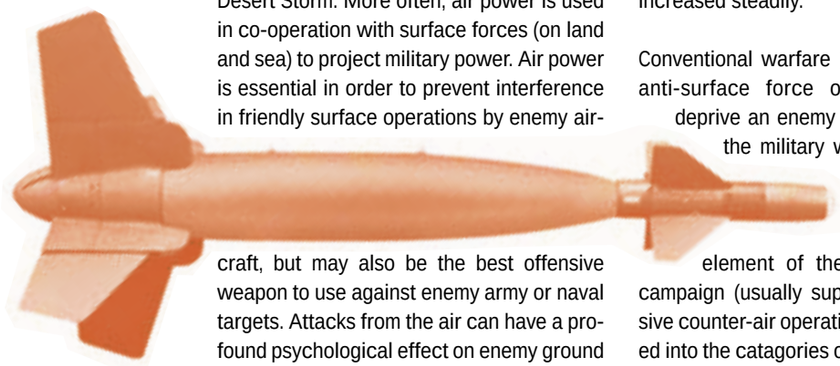
Detailed tactics vary according to the type of weapon being used, since launch envelopes and aspect capabilities can vary quite markedly.

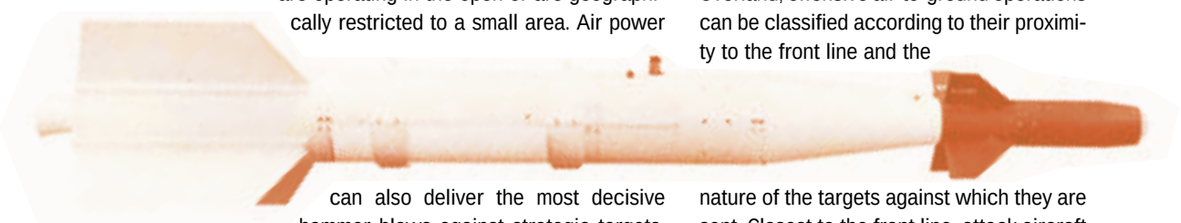
Weapon Systems

Air-to-ground missions and weapons

No war has ever been won by air power alone, since air power cannot physically capture and occupy territory. It can, however, inflict such damage on an enemy that the role of surface forces is limited to occupying territory and supervising a surrender - as was virtually the case during Operation Desert Storm. More often, air power is used in co-operation with surface forces (on land and sea) to project military power. Air power is essential in order to prevent interference in friendly surface operations by enemy aircraft, but may also be the best offensive weapon to use against enemy army or naval targets. Attacks from the air can have a profound psychological effect on enemy ground forces, and can be devastatingly destructive when applied against surface forces that are operating in the open or are geographically restricted to a small area. Air power can also deliver the most decisive hammer blows against strategic targets, and can quite literally destroy the enemy's will to fight on.

Below: **Laser guided bombs in America have been developed under the 'Paveway' code name. Illustrated is the GBU-24A/B of the Paveway III family.**





Above: **This Paveway III LGB is fitted with a rocket booster for a greater stand-off range.**

"Fighters are fun," the old saying goes, "but bombers are important!" Certainly, air-to-ground operations by manned aircraft have often had a decisive influence on the conduct of successive wars, from the RAF's Independent Force in 1918 through the allied bomber campaign against Nazi Germany, Hiroshima, Korea, the various wars of decolonization, the Middle East, Vietnam and the Falklands. Air power has been used decisively against armies in the field, naval vessels and submarines at sea, centers of industry and even enemy civilian populations. As technology has improved, the capabilities of military aircraft have improved almost beyond recognition, and their impact on modern warfare has increased steadily.

Conventional warfare (often referred to as anti-surface force operations) aims to deprive an enemy force commander of the military wherewithal required to occupy territory or exploit control of sea areas. The air element of the anti-surface force campaign (usually supported by an extensive counter-air operation) can be sub-divided into the catagories of; land/air operations and maritime/air operations.

Overland, offensive air-to-ground operations can be classified according to their proximity to the front line and the nature of the targets against which they are sent. Closest to the front line, attack aircraft conduct close air support (CAS) missions, attacking enemy forces in contact with, or in close proximity to, friendly forces. Such missions may have to be closely co-ordinated with friendly fire support, including artillery.

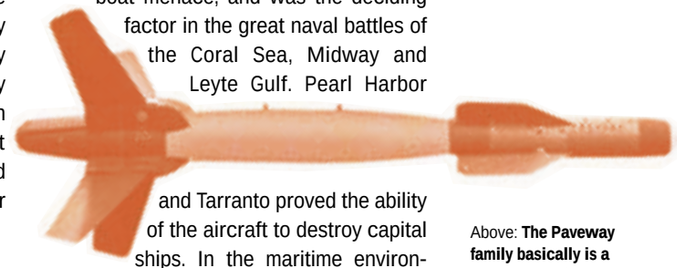
CAS missions may be the only way of rapidly countering enemy breakthroughs or surprise attacks, but are difficult and costly to undertake, because the modern battlefield represents an extremely confused and high-threat environment.

Battlefield air interdiction (BAI) missions are targeted against enemy forces immediately behind the FEBA, which are not yet directly engaged with friendly forces, but which may nevertheless require co-ordination with friendly fire support. BAI missions may cut off the enemy from his reinforcements and often represent a more effective use of air power than CAS sorties.

Tactical air power is most effectively used even further behind the front line, destroying, disrupting or neutralizing enemy military forces (or the enemy's military potential) before they can engage friendly forces. Air interdiction missions are conducted against targets beyond the range of friendly fire support, and therefore do not require detailed co-ordination with friendly artillery and fire support. Interdiction missions hit the most vulnerable targets, forcing the enemy to extend his air defenses over a greater depth. Interdiction may be aimed against supplies for the front line, reinforcements and follow-on forces. Targets may be pre-planned, although interdiction may also be undertaken against targets of opportunity.

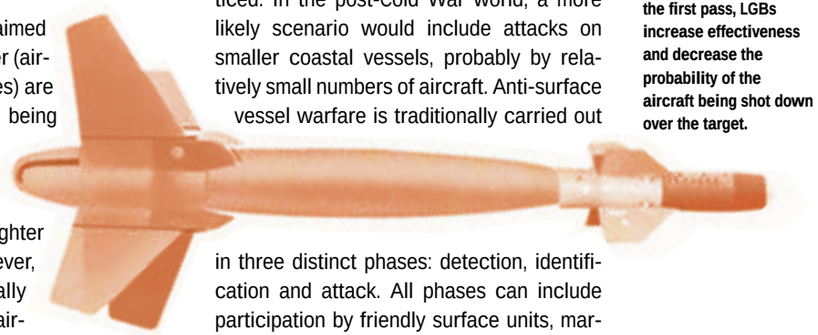
Interdiction missions aimed against enemy air power (airfields and SAM defenses) are usually categorized as being part of the broader offensive counter-air campaign, along with fighter sweeps and fighter escort missions. However, such missions generally use much the same aircraft types, weapons and tactics as other types of air interdiction mission.

Offensive air operations may also be mounted against naval targets. During World War II, air power was crucial in defeating the U-boat menace, and was the deciding factor in the great naval battles of the Coral Sea, Midway and Leyte Gulf. Pearl Harbor and Tarranto proved the ability of the aircraft to destroy capital ships. In the maritime environment, air power can be used to halt and contain the forward movement of enemy naval forces, and can inhibit offensive action by the enemy. Air power has significantly longer reach than do naval forces, and aircraft can be used to attack enemy ships or submarines before they can threaten friendly forces.



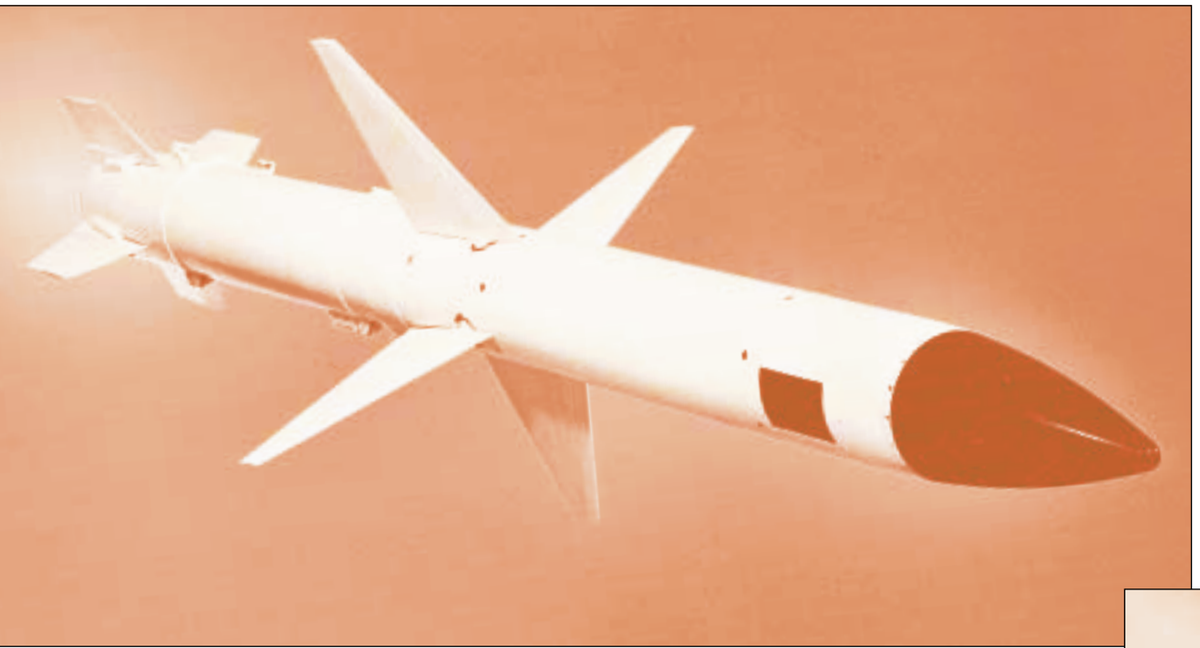
Above: **The Paveway family basically is a conversion kit for existing bombs, adding a laser seeking homer and a set of fins for directional control.**

Anti-ship capabilities reached their zenith at the end of the Cold War, when land-based aircraft might be expected to have to attack large groups of surface warships, including heavily defended capital ships, which might be many miles from shore. Mass attacks by multiple aircraft, each carrying several long-range missiles, were developed and practiced. In the post-Cold War world, a more likely scenario would include attacks on smaller coastal vessels, probably by relatively small numbers of aircraft. Anti-surface vessel warfare is traditionally carried out in three distinct phases: detection, identification and attack. All phases can include participation by friendly surface units, maritime reconnaissance or patrol aircraft and helicopters. Aircraft have a range of unique



Below: **By allowing attacking aircraft a greater probability of destroying the target on the first pass, LGBs increase effectiveness and decrease the probability of the aircraft being shot down over the target.**

Weapon Systems



Above: **The ability to destroy ground based enemy radar systems from the air to allow strike aircraft access to targets unmolested was pioneered in service by the AGM-45 Shrike. Using a radar homing head, Shrike entered service in 1965 and will be in use until the turn of the century.**

capabilities in the maritime environment. Minelaying by aircraft, for example, can be undertaken in areas which may be inaccessible to friendly ships. Anti-surface vessel operations can be carried out by land- or carrier-based fixed-wing aircraft, or even by some ship-based helicopters.

Maritime air operations also include anti-submarine warfare, in which the manned aircraft can play a major part. The likelihood of having to find and destroy ICBM-carrying attack submarines has diminished, but submarines continue to present a potent threat to friendly surface units, being difficult to detect, locate and engage. Aircraft can play a vital role in the surveillance, detection, location and tracking of a submarine, and are often the best platform from which to deploy specialized anti-submarine weapons, such as depth charges or homing torpedoes.

Air power may be used against a variety of strategic targets, including the political leadership, command and control network, military forces, national infrastructure and industrial facilities. Although there is a growing consensus that direct attacks on the civilian population are counter-productive, they are a strategic target. It is the nature of targets (and the intention of the attacks) rather than range which determine whether an operation is strategic or tactical. The strategic air offensive is intended to destroy the enemy's ability and inclination to fight, and can be used to signal political or military intentions, to deter (or even punish) hostile acts, or to threaten escalation of a conflict. Strategic operations can be extremely surgical and can be used to 'take out' a specific capability (e.g., offensive nuclear-biological-chemical weapons or production facilities). Strategic operations are more effective against targets in a developed industrial nation than in a Third World underdeveloped agrarian country, as was shown by the overall failure of the strategic bombing campaign in Vietnam.

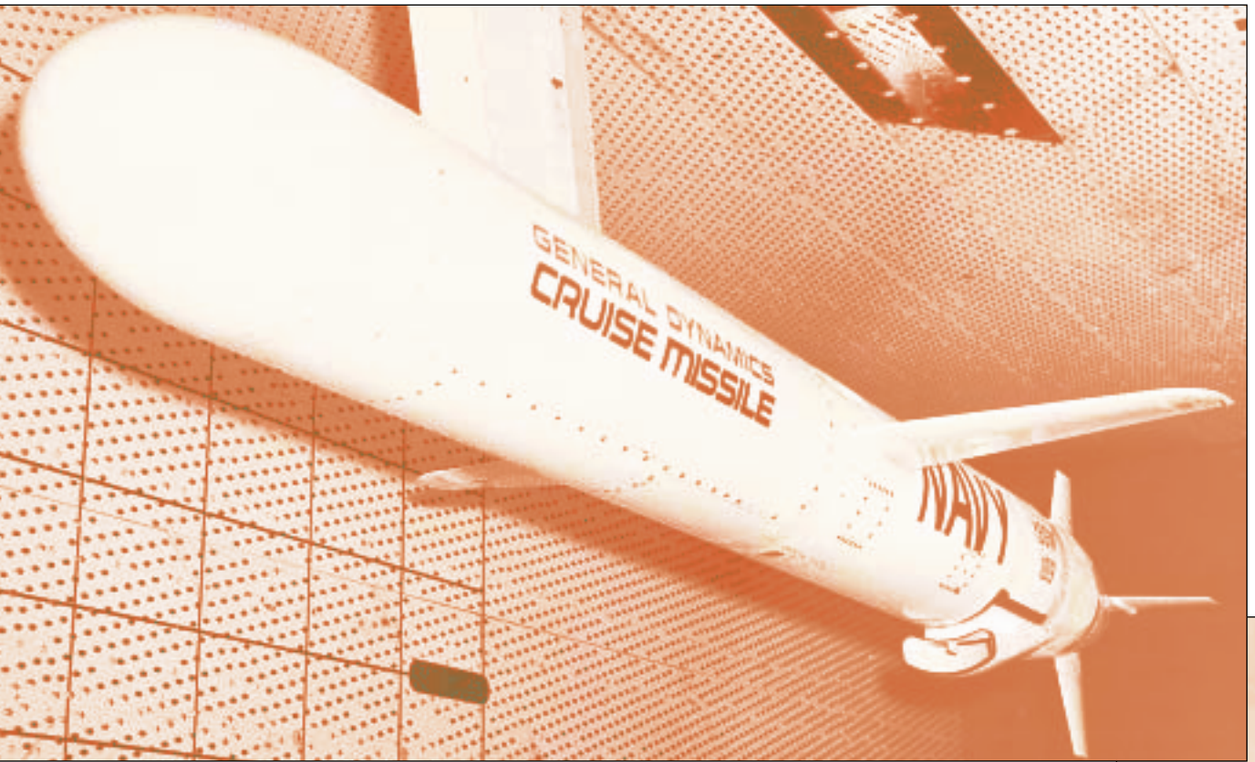
Conventional strategic air operations mounted since World War II have included the attacks on North Korean dams during the Korean War, the Linebacker 2 raids in Vietnam, the Israeli raid on the Iraqi nuclear reactor at Osirak and PLO headquarters in Tunis, the US raids on Libyan targets in 1986, and coalition attacks against Iraqi weapons of mass destruction (and other strategic targets) during the Gulf War.

Nuclear attacks by aircraft are inevitably strategic, since all nuclear powers see such weapons purely as weapons of last resort. Their use is authorized only by the national political leadership, and conveys powerful political signals, however they are targeted. Any nuclear attack (even if made against tactical military targets in the field) is actually a proxy attack on the enemy's political leadership, and is inevitably strategic in effect. Nuclear operations are subject to even tighter political constraints than other strategic missions. Strategic air operations may be carried out independently, but are better when integrated into the overall military campaign.

The main justification for the use of submarine- (or silo-) launched ICBMs lay in their ability to penetrate the most sophisticated ABM defenses (as were found around

Below: **A live firing of a RGM-84A Harpoon missile from a US warship. Harpoon can also be fired from submarines (UGM-84A) or from aircraft (AGM-84A) and is the US Navy's prime anti-surface vehicle missile.**

Weapon Systems



Above: **Seen in the wind-tunnel during its flight test phase is the BQM-109 Tomahawk. The Tomahawk was later to gain fame by being fired from surface ships to targets in Iraq at the start of operation 'Desert Storm'.**

Moscow). In the post-Cold War world, such a capability may be regarded as irrelevant and the greater flexibility of manned aircraft make them more useful as nuclear delivery platforms, since they can be dispersed, launched, recalled and even relaunched, and can fly a wider (and thus more unpredictable) range of sortie profiles. Nuclear-capable aircraft can be rapidly reconfigured to fulfill nuclear strike or conventional attack duties, and are reusable and can be rapidly retasked. Although aircraft can be loaded with nuclear weapons and brought to readiness covertly, such preparations can also be made openly, providing an unmistakable signal to the enemy. Submarines or missile silos cannot be used in the same fashion.

The variety of weapons used for air-to-ground operations is enormous, and there is some crossover between weapons and individual roles, with many of the same aircraft and weapons capable of being tasked in (for example) close air support or interdiction missions. Air-to-ground weapons may be either guided or unguided, powered or unpowered, and can be delivered from a wide range of altitudes, attitudes and sortie profiles. They are fitted with a comprehensive variety of payloads, ranging from simple high explosive to penetrators, minelets and fuel/air explosives, which are specifically designed to cause damage through blast, fragmentation or fire. Some are designed to be simply dropped on a target, others to be lobbed forward onto it, and yet others to be fired from stand-off range.

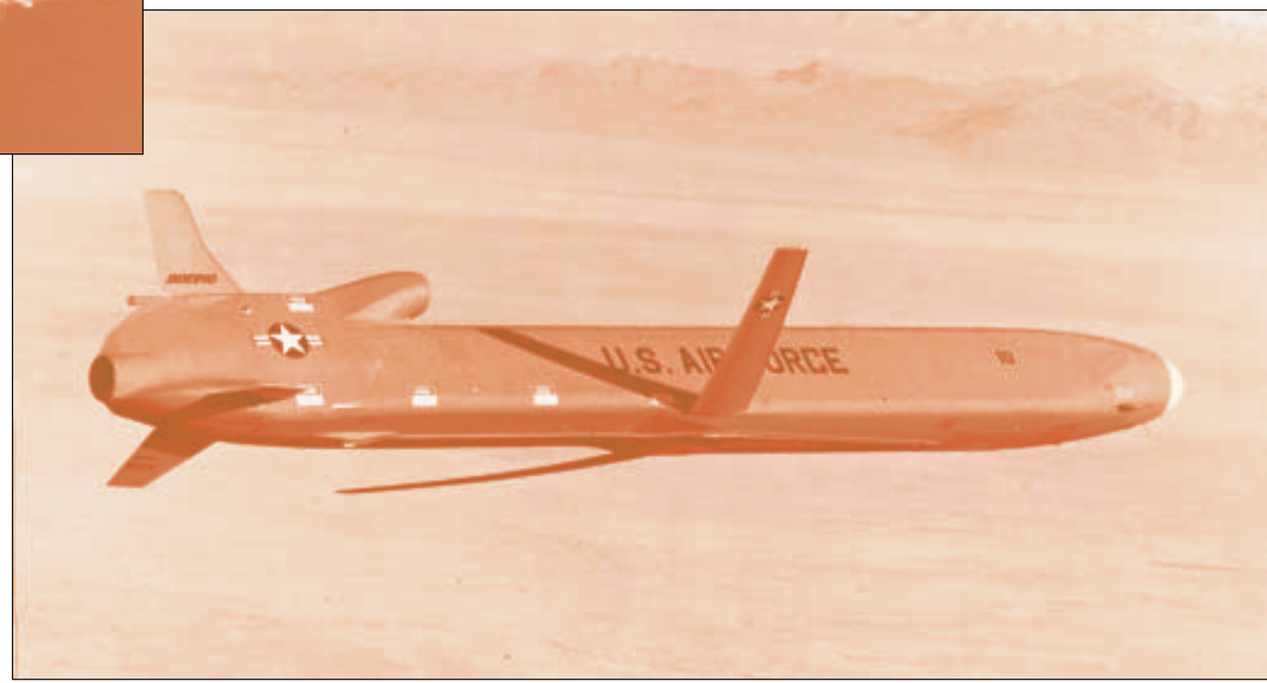
Unguided, unpowered weapons tend to pack a higher explosive content, and may create more damage, or provide superior penetration. Some unguided weapons are powered for greater stand-off capability (or sometimes for penetration). Unguided rockets generally tend to be used as an area weapon, although accuracy can be sufficiently high for them to be used against vehicles or small vessels.

Guided weapons use a variety of guidance systems, some homing on reflected laser or radar energy, some being guided by active radar and others being steered electro-optically, either onto a contrast-locked target or command guided using a TV camera or even tracking flares. Some missiles are even wire guided, either manually, or in some cases, semi-automatically.

Guided weapons are generally used against pinpoint targets, while powered weapons tend to be used against heavily defended targets, where overflight of the target is inadvisable or prohibitively dangerous.

Some offensive maritime air operations use conventional air-to-ground ordnance of the same sort used for some overland operations, though anti-ship and anti-submarine operations more often demand the use of dedicated, specialized weapons, including mines, torpedoes and depth charges, and a variety of specialized missiles.

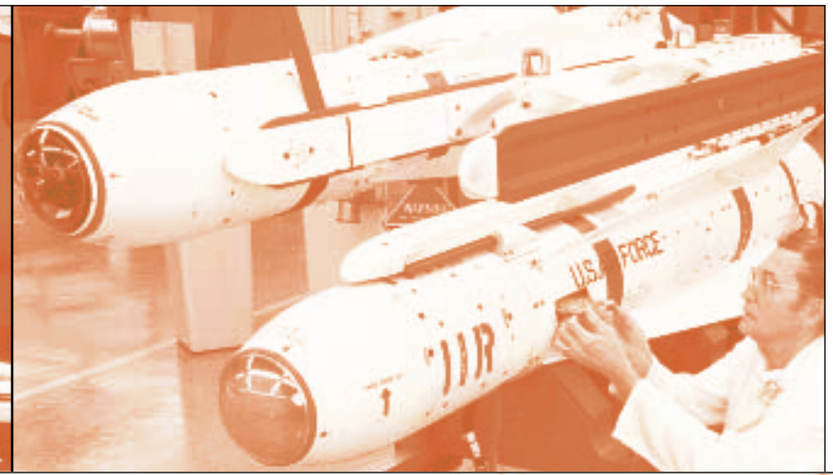
Actual detailed tactics used in air-to-ground



Below: **Designed to give bombers a stand off capability, the AGM-86B Air Launched Cruise Missile (ALCM) is carried by the B-1 and B-52 bombers. The AGM-86B has a nuclear warhead while the 'C' model has a high explosive warhead.**

Weapon Systems

Right: **Attached to a RAF Tornado, the AGM-130 is basically a Mk 84 general purpose bomb fitted with a TV or imaging infrared seeker head, motor and fins. Kits are available to produce this weapon.**



Left: **Two AGM-65 Maverick air-to-surface guided missiles are given the final touches before leaving the factory for the USAF. Over 55,000 have been produced and it is still in production and service.**

Below: **A laser guided bomb on a loading trolley. The chance of hitting a target vastly improved with the development of LGBs, saving money and aircrew lives.**

Above: **The AGM-88 High-Speed Anti-Radar Missile (HARM) is a second generation replacement for the AGM-45 Shrike, entering service in 1983.**

attacks vary widely according to the nature of the target, the demands and limitations of the weapon to be used, and the nature of any threats facing the attacking aircraft.

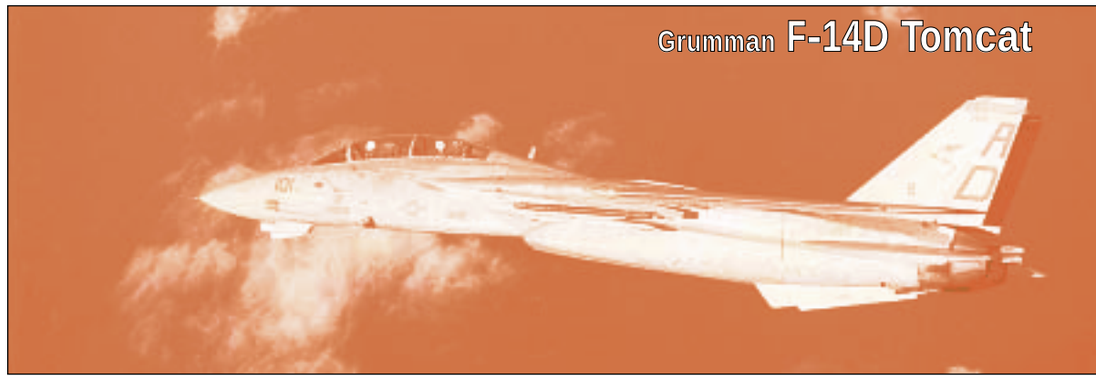
No examination of air-to-ground operations would be complete without mention of radar stealth capability. Only a tiny handful of 'low-observable' aircraft have been deployed, yet they enjoy a significance far beyond their numbers. Although the F-117A has a limited payload, and cannot deliver its weapons in rainy, hazy or cloudy conditions, the aircraft's virtual invisibility to radar allows it to approach a heavily defended target undetected (until it is too late) and deliver two PGMs with great accuracy. This unique capability could be used against enemy troops in contact (the classical CAS mission) as in Panama, against BAI or interdiction targets, or against strategic targets. The larger Northrop B-2 enjoys similar capabili-

Right: **Being fired during trials, the Rapier Darkfire is a developed version of the proven Rapier anti-aircraft system. Like earlier versions, Rapier Darkfire is fully mobile, providing cover to the 'troops on the ground'.**

Above: **Selected in July 1996, the UK's version of the French APACHE air-to-surface missile is known as Storm Shadow. Currently under development, the missile will provide the Tornado attack aircraft force with a long range stand-off missile capability.**

ties, although its low-probability-of-intercept air-to-ground radar gives a degree of all-weather attack capability, and allows the aircraft to locate and attack mobile targets. Stealth is far from being a panacea, and the detectability of aircraft like the F-117A and B-2 is already open to question, but the importance of stealth capability during the late 1980s and early 1990s provides an invaluable illustration of how rapidly technology can affect the way in which air-to-ground operations may be conducted.

Grumman F-14D Tomcat



Wing: span 64 ft 1.5 in (19.54 m) spread, 38 ft 2.5 in (11.65 m) swept and 33 ft 3.5 in (10.15 m) overswept: aspect ratio 7.28 ; area 565.00 sq ft (52.49 m) **Fuselage and tail:** length 62 ft 8 in (19.10m); height 16 ft 0 in (4.88 m) tailplane span 32 ft 8.5 in (9.97 m); wheel track 16 ft 5 in (5.00 m); wheel base 23 ft 0 in (7.02 m) **Powerplant:** two General Electric F110-GE-400 turbofans each rated at 14,000 lb st (62.27 kN) dry and 23,100 lb st (102.75 kN) with afterburning **Weights:** empty 41,780 lb (18951 kg); normal take-off 64,093 lb (29072 kg) for a fighter/escort mission or 73,098 lb (33157 kg) on a fleet air defense mission; maximum take-off 74,349 lb (33724 kg) lb **Speed:** maximum level speed 'clean' at high altitude 1,078 kt (1,241 mph; 1997 km/h); cruising speed at optimum altitude 413 kt (475 mph; 764 km/h) **Range:** maximum range with internal and external fuel about 1,600 nm (1,842 miles; 2965 km); combat radius on a combat air patrol with six AIM-7 Sparrows and four AIM-9 Sidewinders 1,075 nm (1,239 miles; 1994 km) **Performance:** maximum rate of climb at sea level more than 30,000 ft (9145 m) per minute; service ceiling more than 53,000 ft (16150 m); take-off run 2,500 ft (762 m) from land at maximum take-off weight; landing run 2,400 ft (732 m) on land

McDonnell Douglas F-15C Eagle

Wing: span 42 ft 9.75 in (13.05 m); aspect ratio 3.01; area 608.00 sq ft (56.48 m2) **Fuselage and tail:** length 63 ft 9 in (19.43 m); height 18 ft 5.5 in (5.63 m); tailplane span 28 ft 3 in (8.61 m); wheel track 9 ft 0.25 in (2.75 m); wheel base 17 ft 9.5 in (5.42 m) **Powerplant:** two Pratt & Whitney F100-PW-220 turbofans each rated at 14,670 lb st (65.26 kN) dry and 23,830 lb st (106.0 kN) with afterburning **Weights:** operating empty 28,600 lb (12793 kg); normal take-off 44,630 lb (20244 kg) on an interception mission with four AIM-7 Sparrow AAMs; maximum take-off 58,470 lb (26521 kg) with three 610-US gal (2309-litre) drop tanks or 68,000 lb (30844 kg) with CFTs **Fuel and load:** internal fuel 13,455 lb (6103 kg); external fuel up to 9,750 lb (4423 kg) in two CFTs and 11,895 lb (5395 kg) in three 600-US gal (2271-litre) drop tanks; maximum ordnance 16,000 or 23,600 lb (7257 or 10705 kg) without or with CFTs respectively **Speed:** maximum level speed 'clean' at 36,000 ft (10975 m) more than 1,433 kt (1,650 mph; 2655 km/h); cruising speed at optimum altitude 495 kt (570 mph; 917 km/h) **Range:** ferry range with drop tanks more than 2,500 or 3,100 nm (2,879 or 3,570 miles; 4633 or 5745 km) without or with CFTs respectively; combat radius on an interception mission 1,061 nm (1,222 miles; 1967 km); endurance 5 hours 15 minutes with CFTs or 15 hours with flight refueling **Performance:** maximum rate of climb at sea level more than 50,000 ft (15240 m) per minute; service ceiling 60,000 ft (18290 m); absolute ceiling 100,000 ft (30480 m); take-off run 900 ft (274 m) at normal take-off weight; landing run 3,500 ft (1067 m) at normal landing weight without a brake parachute **g limits:** -3 to +9

Lockheed (General Dynamics) F-16C Fighting Falcon

Wing: span 31 ft 0 in (9.45 m) without tip-mounted AAMs and 32 ft 9.75 in (10.00 m) with tip-mounted AAMs; aspect ratio 3.09; area 300.00 sq ft (28.87 m2) **Fuselage and tail:** length 49 ft 4 in (15.03 in); height 16 ft 8.5 in (5.09 m); tailplane span 18 ft 3.75 in (5.58 m); wheel track 7 ft 9 in (2.36 m); wheel base 13 ft 1.5 in (4.00 m) **Powerplant:** (see text for sub-variant) one Pratt & Whitney F100-P-220 turbofan rated at 23,450 lb st (104.31 kN) with afterburning or one General Electric F110-GE-100 turbofan rated at 27,600 lb st (122.77 kN) with afterburning **Weights:** empty 19,100 lb (8663 kg) with F110 turbofan or 18,335 lb (8316 kg) with F100 turbofan; typical combat take-off 21,585 lb (9791 kg); maximum take-off 25,071 lb (11372 kg) for an air-to-air mission without drop tanks or 42,300 lb (19187 kg) with maximum external load **Fuel and load:** internal fuel 6,972 lb (3162 kg); external fuel up to 6,760 lb (3066 kg) in three 300-, 370-, 450- and 600-US gal (1136-, 1400-, 1703- and 2271-litre) drop tanks; maximum ordnance 15,200 lb (6894 kg) **Speed:** maximum level speed 'clean' at 40,000 ft (12190 m) more than 1,146 kt (1,320 mph; 2124 km/h) and at sea level 795 kt (915 mph; 1472 km/h) **Range:** ferry range more than 2,100 nm (2,418 miles; 3891 km) with drop tanks; combat radius 295 nm (340 miles; 547 km) on a hi-lo-hi mission with six 454 kg (1,000 lb) bombs **Performance:** maximum rate of climb at sea level more than 50,000 ft (15240 m) per minute; service ceiling more than 50,000 ft (15420 m) **g limits:** +9

McDonnell Douglas F/A-18E 'Super Hornet'

Wing: span 41 ft 10.25 in (12.76 m) without tip-mounted AAMs and 44 ft 8.5 in (13.62 m) with tip-mounted AAMs; width folded 30 ft 7.25 in (9.32 m); aspect ratio 3.51; area 500.00 sq ft (46.45 m2) **Fuselage and tail:** length 60 ft 1.25 in (18.31 m); height 15 ft 9.5 in (4.82 m) **Powerplant:** two General Electric F414-GE-400 turbofans each rated at 22,000 lb st (97.86 kN) with afterburning **Weights:** empty 30,600 lb (13880 kg); maximum take-off 66,000 lb (29937 kg) **Fuel and load:** internal fuel 14,400 lb (6531 kg); external fuel up to 9,780 lb (4436 kg) in three 480-US gal (1818-liter) fuel tanks; maximum ordnance 17,750 lb (8051 kg) **Speed:** maximum level speed 'clean' at high altitude more than 1,033 kt (1,190 mph; 1915 km/h) **Range:** combat radius 591 nm (681 miles; 1095 km) on a hi-hi-hi interdiction mission with four 1,000-lb (454-kg) bombs, two AIM-9 Sidewinder AAMs and two fuel tanks, or 486 nm (560 miles; 901 km) on a hi-lo-hi interdiction mission with the same stores, or 150 nm (173 miles; 278 km) on a 135minute maritime air superiority mission with six AAMs and three fuel tanks **Performance:** combat ceiling about 50,000 ft (15240 m)

Sukhoi Su-27 'Flanker-B'

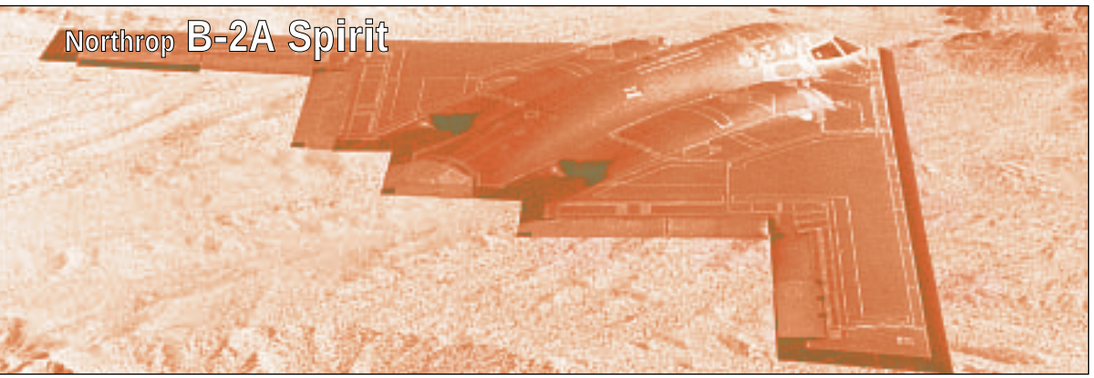
Wing: span 14.70 m (48 ft 2.75 in); aspect ratio 5.6; wing area 46.50 m2 (500.54 sq ft) **Fuselage and tail:** length 21.90 m (71 ft 10 in) excluding probe; height 5.90 m (19 ft 4 in); tailplane span 9.90 m (32 ft 6 in); wheel track 4.33 m (14 ft 2½ in); wheel base 5.88 m (19 ft 3.5 in) **Powerplant:** two NPO Saturn (Lyul'ka) AL-31F turbofans each rated at 79.43 kN (17,857 lb) dry and 122.58 kN (27,557 lb st) with afterburning **Weights:** empty 17700 kg (39,021 lb); normal take-off 23250 kg (51,257 lb); maximum take-off 33000 kg (72751 lb) **Fuel and load:** normal internal fuel about 527 (11,618 lb); maximum internal fuel 9400 kg (20,723 lb); maximum ordnance 6000 kg (13,228 lb) **Speed:** limiting Mach No. 2.35; maximum level speed 'clean' at 11000 m (36,090 ft) 2280 km/h (1230 kt; 1417 mph) and at sea level 1370 km/h (739 kt; 851 mph) **Range:** at high-altitude 3680 km (1,986 nm; 2,287 miles); range at low-altitude 1370 km (739 nm; 851 miles) **Performance:** maximum rate of climb at sea level 19800 m (64,960 ft) per minute; service ceiling 17700 m 58,071 ft); take-off run 450 m (1,476 ft) at maximum take-off weight; landing run 700 m (2,297 ft) at normal landing weight **g limits:** +8

Lockheed Martin F-117A Night Hawk

Wing: span 43 ft 4 in (13.20 m); aspect ratio about 4.3; area about 1,140.00 sq ft (105.9 m2) **Fuselage and tail:** length 65 ft 11 in (20.08 m); height 12 ft 5 in (3.78 m) **Powerplant:** two General Electric F404-GE-F1D2 each rated at 10,800 lb st (48.04 kN) dry **Weights:** empty about 30,000 lb (13608 kg); maximum take-off 52,500 lb (23814 kg) **Fuel and load:** maximum ordnance 5,000 lb (2268 kg) **Speed:** maximum level speed 'clean' at high altitude possibly more than Mach 1; normal maximum operating speed at optimum altitude Mach 0.9 **Range:** combat radius about 600 nm (691 miles; 1112 km) with maximum ordnance **g limits:** +6

Strike Aircraft

Northrop B-2A Spirit

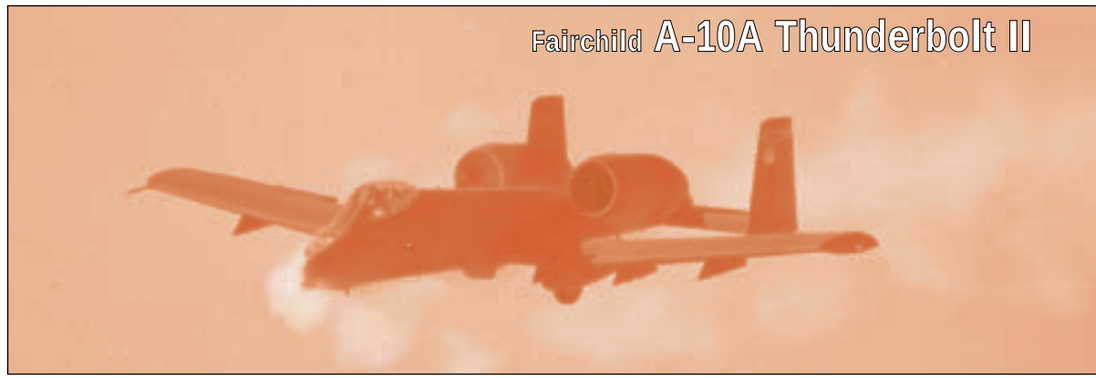


Wing: span 172 ft 0 in (52.43 m); aspect ratio more than 5.92; area more than 5,000.00 sq ft (464.50 m2) **Fuselage:** length 69 ft 0 in (21.03 m); height 17 ft 0 in (5.18 m); wheel track 40 ft 0 in (12.20 m) **Powerplant:** four General Electric F118-GE-110 non-afterburning turbofans each rated at 19,000 lb st (84.52 kN) **Weights:** empty between 100,000 and 110,000 lb (45360 and 49900 kg); normal take-off 371,330 lb (168433 kg); maximum take-off 400,000 lb (181437 kg) **Fuel and load:** internal fuel between 180,000 and 200,000 lb (81650 and 90720 kg); external fuel none; maximum ordnance 50,000 lb (22680 kg) **Speed:** maximum level speed at high altitude about 416 kt (475 mph; 764 km/h) **Range:** more than 10,000 nm (11,515 miles; 18532 km) with one flight refueling; range with a 37,300-lb (169219-kg) warload comprising eight SRAMs and eight B83 bombs 6,300 nm (7,255 miles; 11675 km) with internal fuel on a hi-hi-hi mission or 4,400 nm (5,067 miles; 8154 km) on a hi-lo-hi mission with 1,000 nm (1,152 miles; 1853 km) at low level; range with a 24,000-lb (10886-kg) warload comprising eight SRAMs and eight B61 bombs 6,600 nm (7,600 miles; 12231 km) with internal fuel on a hi-hi-hi mission or 4,500 nm (5,182 miles; 8339 km) with internal fuel on a hi-lo-hi mission **Performance:** service ceiling 50,000 ft (15240 m)

McDonnell Douglas F-15E Eagle

Wing: span 42 ft 9.75 in (13.05 m); aspect ratio 3.01; area 608.00 sq ft (56.48 m2) **Fuselage and tail:** length 63 ft 9 in (19.43 m); height 18 ft 5.5 in (5.63 m); tailplane span 28 ft 3 in (8.61 m); wheel track 9 ft 0.25 in (2.75 m); wheel base 17 ft 9.5 in (5.42 m) **Powerplant:** two Pratt & Whitney F100-P-220 turbofans each rated at 14,670 lb st (65.26 kN) dry and 23,830 lb st (106.0 kN) with afterburning or, in aircraft built after August 1991, two F100-PW-229 each rated at 17,800 lb st (79.18 kN) dry and 29,100 lb st (129.45 kN) with afterburning; option of two General Electric F110-GE-129 each rated at 17,000 lb st (75.62 kN) dry and 29,000 lb st (129.0 kN) with afterburning **Weights:** operating empty 31,700 lb (14379 kg); maximum take-off 81,000 lb (36741 kg) **Fuel and load:** internal fuel 13,123 lb (5952 kg); external fuel 21,645 lb (9818 kg) in two CFTs and up to three 610-US gal (2309-liter) drop tanks; maximum ordnance 24,500 lb (11113 kg) **Speed:** maximum level speed 'clean' at high altitude more than 1,433 kt (1,650 mph; 2655 km/h); cruising speed at optimum altitude 495 kt (570 mph; 917 km/h) **Range:** ferry range 3,100 nm (3,570 miles; 5745 km) with CFTs and drop tanks, or 2,400 nm (2,765 miles; 4445 km) with drop tanks; combat radius 685 nm (790 miles; 1270 km) **Performance:** maximum rate of climb at sea level more than 50,000 ft (15240 m) per minute; service ceiling 60,000 ft (18290 m); landing run 3,500 ft (1067 m) at normal landing weight without braking parachute

Fairchild A-10A Thunderbolt II



Wing: span 57 ft 6 in (17.53 m); aspect ratio 6.54; area 506.00 sq ft (47.01 m2) **Fuselage and tail:** length 53 ft 4 in (16.26 m); height 14 ft 8 in (4.47 m); wheel track 17 ft 2.5 in (5.25 m) **Powerplant:** two General Electric TF34-GE100 each rated at 9,065 lb st (40.32 kN) **Weights:** basic empty 21,541 lb (45360 and 49900 kg); operating empty 24,959 lb (11321 kg); forward airstrip armed 32,771 lb (14865 kg); maximum take-off 50,000 lb (22680) **Fuel and load:** internal fuel 10,700 lb (4853 kg); external fuel up to three US gal (2271 liter) drop tanks; maximum ordnance 16,000 lb (7258 kg) or, with internal fuel, 14,341 lbs (6505 Kg) **Speed:** never-exceed speed 450 kt (518 mph; 834 km/h) maximum level speed'clean' at sea level 381 kt (439 mph; 706km/h) **Range:** ferry range 2,131 nm (2,454 miles; 3949 km) with drop tanks; combat radius 540 nm (620 miles; 1000km) on a deep strike mission or 250 nm (288 miles; 463 km) on a close air support mission with a 1.7 hour loiter **Performance:** maximum rate of climb at sea level 6,000 ft (1828 m) per minute; take-off run 4,000 ft (1220 m) at maximum take-off weight or 1,450 ft (442m) at forward strip weight; landing run 2,000 ft (610 m) at maximum weight or 1,300 ft (396) at forward strip weight

Panavia Tornado GR.Mk 1

Wing: span 45 ft 7.5 in (13.91 m) minimum sweep (25°) and 28 ft 2.5 in (8.60 m) maximum sweep (67°); aspect ratio 7.73 spread and 2.96 swept; area 286.33 sq ft (26.60 m2) **Fuselage and tail:** length 54 ft 10.25 in (16.72 m); height 19 ft 6.25 in (5.95 m); tailplane span 22 ft 3.5 in (6.80 m); wheel track 10 ft 2 in (3.10 m); wheel base 20 ft 4 in (6.20 m) **Powerplant:** two Turbo-Union RB.199-34R Mk 101 turbofans each rated at 8,475 lb st (37.70 kN) dry and 14,840 lb st (66.01 kN) with afterburning or, in later aircraft, Turbo-Union RB.199-34R Mk 103 turbofans each rated at 8,650 lb st (38.48 kN) dry and 16,075 lb st (71.50 kN) with afterburning **Weights:** basic empty about 30,620 lb (13890 kg); operating empty 31,065 lb (14091 kg); normal take-off 45,000 lb (20411 kg); maximum take-off about 61,620 lb (27951 kg) **Fuel and load:** internal fuel 11,221 lb (5090 kg); external fuel up to 13,200 lb (5988 kg) in two 2250-liter (396-US gal) and two 1500-liter (396-US gal) or four 1500-liter (396-US gal) drop tanks; nominal maximum ordnance more than 9000 kg (19,841 lb) **Speed:** limiting Mach No. Mach 1.4 with LRMTS, M1.3 with intakes deactivated ; limiting IAS 1482 km/h ; maximum level speed 'clean' at 36,000 ft 1,262 kt **Range:** ferry range about 2,100 nm (2,420 miles; 3890 km) with four drop tanks; combat radius 750 nm (863 miles; 1390 km) on a hi-lo-hi attack mission with a heavy warload **Performance:** climb to 30,000 ft in less than 2 minutes 0 seconds from brakes-off; service ceiling more than 50,000 ft; take-off run less than 900 m at maximum take-off weight **g limits:** +7.5

Strike Aircraft

British Aerospace/McDonnell Douglas Harrier GR.Mk 7

Wings: span 30 ft 4 in (9.25 m); aspect ratio 238,7 sq ft (22.18 m2) including 8.70 sq ft (0.81 m2) for the two LERXes **Fuselage and tail:** length 47 ft 1.5 in (14.36 m); height 11 ft 7.75 in (3.55 m); tailplane span 13 ft 11 in (4,24 m); outrigger wheel track 17 ft 0 in (5.18 m) **Powerplant:** one Rolls-Royce Pegasus Mk 105 rated at 21,750 lb st (96.75 kN) dry **Weights:** operating empty 15,542 lb (7050 kg) including pilot and unused fuel; normal take-off 22,950 lb (10410 kg) for STO; maximum take-off 31,000 lb (14061 kg) for STO or 18,950 lb (8595 kg) for VTO **Fuel and load:** internal fuel 7,759 lb (3519 kg); external fuel up to 8,071 lb (3661 kg) in four 250-Imp gal (300-US gal; 1136 liter) drop tanks; maximum ordnance 9,200 lb (4173 kg) **Speed:** maximum level speed 'clean' at 36,000 ft (10975 m) 522 kt (601 mph; 967 km/h) and 575 kt (661 mph; 1065 km/h) at sea level **Range:** ferry range 2,000 nm (2,418 miles; 3891 km) with empty tanks dropped or 1,750 nm (2,015 miles: 3,243 km) with empty tanks retained; combat radius 90 nm (103 miles; 167 km) after STO on a lo-lo-lo attack mission with a 1-hour loiter carrying 12 500 lb (227 kg) bombs, or 480 nm (553 miles; 889 km) after STO on a hi-lo-hi attack mission with seven 500 lb (227 kg) bombs. **Performance:** take-off run 1,330 ft (405 m) at maximum take-off weight; landing run 0 ft (0 m) at normal landing weight **g limits:** -3 to + 8

Dassault Mirage 2000N

Wing: span 9.29 m (30 ft 4.5 in); aspect ratio 2.03 **Fuselage and tail:** length 14.55 m (47 ft 9 in); height 5.15 m (16 ft 10.75 in): wheel track 3.40 m (11 ft 1.75 in); wheel base 5.00 m (16 ft 4.75 in) **Powerplant:** one SNECMA M53-P2 rated at 64.33kN (14,462 lb st) dry and 95.12 kN (21,384 lb st) with afterburning **Weights:** empty 7500 kg (16,534 lb): normal take-off 10680 kg (23,545 lb); maximum take-off 17000 kg (37,478 lb) **Fuel and load:** internal fuel 3160 kg ; external fuel up to 3720 kg (8,201 lb) in one 1300-liter (343-US gal) and two 1700-liter drop tanks; maximum ordnance 16300 kg (13,890 lb) **Speed:** maximum level speed 'clean' at 11000 m (36,090 ft) 2338 km/h (1,262 kt; 1,453 mph); penetration speed at 60 m (197 ft) 1112 km/h (600 kt; 691 mph) **Range:** ferry range 3335 km (1,800 nm; 2072 miles) with drop tanks; combat range more than 1480 km with four 250 kg bombs, or more than 1850 km with two drop tanks **Performance:** maximum rate of climb at sea level 17060 m (55,971 ft) per minute; service ceiling 18000 m (59,055 ft); climb to 15000m (49,215 ft) 4 minutes; time to intercept a Mach 3 target at 24400 m (80,050 ft) from brakes off less than 5 minutes; take-off run about 450 m (1,476 ft) at normal take-off weight **g limits:** +9 normal and +13.5 ultimate

Mikoyan MiG-27 'Flogger-D'

Wing: span 13.97 m spread and 7.78 m (25 ft 6.25 in) swept; aspect ratio 5.22 spread and 1.77 swept; area 37.35 m2 (402.05 sq ft) spread and 34.16 m2 (367.71 sq ft) swept **Fuselage and tail:** length 17.08 m (56 ft 0.25 in) including probe; height 5.00 m (16 ft 5 in); tailplane span 5.75 m (18 ft 10.25 in); wheel track 2.66 m (8 ft 8.75 in); wheel base 5.772 m (18 ft 11.25 in) **Powerplant:** one MNPK 'Soyuz' (Tumanskii) R-29B-300 turbojet rated at 78.45 kN (17,637 lb st) dry and 112.77 kN (25,353 lb st) with afterburning **Weights:** empty equipped 11908 kg (26,252 lb); normal take-off 18100 kg (39,903 lb); maximum take-off 20300 kg (44,753 lb) **Fuel and load:** internal fuel 4560 kg (10,053 lb); external fuel up to three 790-liter (209-US gal) drop tanks; maximum ordnance more than 4000 kg (8,818 lb) **Speed:** maximum level speed 'clean' at 8000 m (26,245 ft) 1885 km/h (1,017 kt; 1,170 mph) or at sea level 1350 km/h (728 kt; 839 mph) **Range:** combat radius 540 km (291 nm; 335 miles) on a lo-lo-lo attack mission with two Kh-29 ASMs and three drop tanks, or 225 km (121 nm; 140 miles) with two Kh-29 ASMs **Performance:** maximum rate of climb at sea level 12000 m (39,370 ft) per minute; service ceiling 14000 m (45,930 ft); take-off run 950 m (3,117 ft) at maximum take-off weight; landing run 1300 m (4,265 ft) at normal landing weight without brake chute or 900 m (2,953 ft) at normal landing weight with brake chute **g limits:** +7.0

Sukhoi Su-25TM

Wing: span 14.52 m (47 ft 7.75 in); aspect ratio 7.0; area 30.10 m2 (324.0 sq ft) **Fuselage and tail:** length 15.35 m (50 ft 4.5 in); height 5.20 m (17 ft 0.75 in) **Powerplant:** two Improved Soyuz/Tumansky R-195Sh turbojets rated at 44.13 kN (9,921 lb st) **Weights:** empty equipped 9800 kg (21,605 lb); normal take off 14600 kg (32,187 lb); maximum take 20,500 kg (45,194 lb) **Fuel and Load:** maximum internal fuel 3,840 kg (8,465 lb); maximum external fuel 3,070 kg (6,768 lb); maximum ordnance 5,000 kg (11,023 lb) **Speed:** maximum level speed 'clean' at sea level 950 km/h (513 kt; 590 mph) **Range:** combat radius 400 km (216 n miles; 248 miles) on a low altitude attack mission with 2,000 kg (4,410 lb) of weapons; ferry range 2,250 km (1,214 n miles; 1,398 miles) **Performance:** service ceiling 10,000 m (32,800 ft); take-off run 650 m (2,135 ft); landing run 750 m (2,465 ft)

Sukhoi Su-30MK

Wing: span 14.70 m (48 ft 2.75 in); aspect ratio 3.5; area 62.0 m2 (667.4 sq ft) **Fuselage and tail:** length 21.94 m (71 ft 11.5 in); height 6.355 m (20 ft 10.25 in) **Powerplant:** two Saturn/Lyulka AL-31F turbofans, each 122.6 kN (27,557 lb st) with afterburning **Weights:** empty weight 17,700 kg (39,022 lb); normal take-off weight 17,700 kg (39,022 lb); maximum take-off weight 33,000 kg (72,752 lb) **Fuel and Load:** normal internal fuel about 5270 kg (11,618 lb); maximum internal fuel 9400 kg (20,723 lb); maximum ordnance 6000 kg (13,228 lb) **Speed:** limiting mach 2.35; maximum level speed 'clean' at 11000 m (36,090 ft) 2280 m km/h (1230 kt; 1417 mph) and at sea level 1370 km/h (739 kt; 851 mph) **Range:** combat range on internal fuel 3,000 km (1,620 n miles; 1,865 miles) **Performance:** maximum rate of climb at sea level 19800 m (64,960 ft) per minute; service ceiling 17700 m (58,071 ft); take-off run 550 m (1,805 ft); landing run 670 m (2,200 ft) **g Limits:** + 8

Sukhoi Su-34

Wing: span 14.70 m (48 ft 2.75 in); aspect ratio 5.6; wing area 46.50 m2 (500.54 sq ft) **Fuselage and tail:** length 21.90 m (71 ft 10 in) height 5.90 m (19 ft 4 in); tailplane span 9.90 m (32 ft 6 in); wheel track 4.33 m (14 ft 2.5 in); wheel base 5.88 m (19 ft 3.5 in) **Powerplant:** Two NPO Saturn/Lyul'ka, AL-31FM turbofans, each rated at 130.42 kN (29,320 lb st) with afterburning) **Weights:** empty 17700 kg (39,021 lb); normal take-off 23250 kg (51,257 lb); maximum take off 44,360 kg (97,795 lb) **Fuel and load:** normal internal fuel load about 5270 kg (11,618 lb);maximum internal fuel 9400 kg (20,723 lb); maximum ordnance 8,000 kg (17,636 lb) **Speed:** limiting Mach 2.35; maximum level speed at 11000 m (36,000 ft) Mach 1.8 and at sea level Mach 1.15 1,400 km/h; 870 mph) **Range:** with maximum internal fuel 4,000 km (2,160 km: 2,485 miles) **Performance:** maximum rate of climb at sea level 19800 m (64,960 ft) per minute: service ceiling 17,000 m (55,755 ft): take-off run 450 m (1,476 ft) at maximum take-off weight; landing run 700 m (2,297 ft) at normal landing weight **g limits:** + 8

Lockheed U-2S

Wing: span 103 ft 0 in (31.39 m); aspect ratio 10.6; area about 1,000.00 sq ft (92.90 m2) **Fuselage and tail:** length 62 ft 9 in (19.13 m); height 16 ft 0 in (4.88 m) **Powerplant:** one General Electric F101-GE-F29 rated at 19,000 lb st (84.5 kN) dry **Weights:** basic empty without powerplant and equipment pods less than 10,000 lb (4536 kg); operating empty about 15,500 lb (7031 kg); maximum take-off 41,300 lb (18733 kg) **Fuel and load:** internal fuel 7,649 lb (3469 kg); external fuel none; sensor weight 3,000 lb (1361 kg) **Speed:** never exceed speed Mach 0.8; maximum cruising speed at 70,000 ft (21335 m) more than 373 kt (430 mph; 692 km/h) **Range:** maximum range about 5,428 nm (6,250 miles; 10060 km); maximum endurance 12 hours **Performance:** maximum rate of climb at sea level about 5,000 ft (1525 m) per minute; climb to 65,000 ft (19810 m) in 35 minutes; operational ceiling 80,000 ft (24385 m); take-off run about 650 ft (198 m) at maximum take-off weight; landing run about 2,500 ft (762 m) at maximum landing weight

Lockheed EC-130E Hercules

Wing: span 132 ft 7 in (40.41 m): aspect ratio 10.09 area 1,745.00 sq ft (161.12 m2) **Fuselage and tail:** length 97 ft 9 in (29.79 m); height 38 ft 3 in (11.66 m); tailplane span 52 ft 8 in (16.05 m); wheel track 14 ft 3 in (4.35 m); wheel base 32 ft 0.75 in (9.77 m) **Powerplants:** four Allison T56-A-7 turboprops each rated at 4,050 ehp (3020 ekW) **Weights:** empty 72,892 lb (33063 kg); maximum payload 45,000 lb (20412 kg) **Fuel and load:** internal fuel 5,050 US gal (19116 liters); external fuel two 450 US gal (1703 liter) underwing tanks; maximum payload 35,700 lb (16194 kg) **Speed:** maximum speed at 30,000 ft (9145 m) 330 kt (380 mph; 612 km/h); cruising speed 320 kt (362 mph; 592 km/h) **Range:** 4,080 nm (4,698 miles; 7560 km) **Performance:** maximum rate of climb at sea level 1,830 ft (558 m) per minute; service ceiling 34,000 ft (10365 m); take off distance to 50 ft (15 m) 4,300 ft (1311 m) at maximum take off weight

Mikoyan-Gurevich MiG-25RB 'Foxbat-B'

Wing: span 13.42 m (44 ft 0.25 in) **Fuselage and tail:** length 23.82 m (78 ft 1.75 in); height 6.10 m (20 ft 0.25 in); wheel track 3.85 m (12 ft 7.5 in); wheel base 5.14 m (16 ft 10.5 in) **Powerplant:** two MNPK 'Soyez' (Tumanskii) R-158D-300D turbojets each rated at 109.83 kN (24,691 lb st) with afterburning **Weights:** normal take-off 37000 kg (81,570 lb); maximum take-off 41200 kg (90,829 lb) **Fuel and load:** internal fuel 15245 kg (33,609 lb); maximum ordnance 3000 kg (6,614 lb) **Speed:** maximum level speed 'clean' at 13000 m (42,650 ft) Mach 2.8 or 3000 km/h (1,619 kt; 1,864 mph) and at sea level 1200 km/h (647 kt; 745 mph) **Range:** ferry range with underbelly tank 2400 km (1,295 nm; 1,491 miles) subsonic or 2130 km (1150 nm; 1,323 miles) supersonic; range with internal fuel 1865 km (1,006 nm; 1,158 miles) subsonic or 1635 km (882 nm; 1,015 miles) supersonic **Performance:** climb to 19000 m (41,885 ft) in 6 minutes 36 seconds 'clean' or 8 minutes 12 seconds with 2000 kg (4,409 lb) of bombs; service ceiling 21000 m (68,900 ft)

Myasishchev M-17 Stratosfera 'Mystic-A'

Wing: span 40.70 m (133 ft 6.5 in) **Fuselage and tail:** length 21.20 m (69 ft 6.5 in); height 5.25 m (17 ft 3 in); wheel track 6.65 m (21 ft 10 in); wheel base 5.60 m (18 ft 4.5 in) **Powerplant:** one RKBM (Novikov) RD-36-51V turbojet rated at 68.65 kN (15,432 lb st) **Weights:** maximum take-off 19950 kg (43,981 lb) **Fuel and load:** external fuel none **Range:** endurance 2 hours 30 minutes **Performance:** service ceiling 20000 m (65,615 ft)

Teledyne Ryan Model 367 Global Hawk (Tier II +)

Wing: span 35.42 m (116 ft 2.4 in); wing area 50.17 m2 (540.0 sq ft); wing aspect ratio 25.00 **Fuselage and tail:** Length 13.53 m (44 ft 4.8 in); height overall 4.63 m (15 ft 2.4 in); wheel track approx. 3.28 m (10 ft 9.0 in); wheelbase approx. 4.50 m (14 ft 9.0 in) **Powerplant:** one 32.03 kN (7,200 lb st) Allison AE 3007H turbofan **Weights:** weight empty 3,469 kg (7,648 lb); maximum take-off weight 10,394 kg (22,914 lb) **Fuel and Load:** Maximum fuel weight 6,445 kg (14,210 lb): maximum payload 907 kg (2,000 lb) **Speed:** Loiter speed 343 kts (635 km/h: 395 mph) **Range:** Ferry range 14,450 n miles (26,761 km: 16,629 miles)

Lockheed Martin/Boeing Model 944B DarkStar (Tier III-)

Wing: span 21.03 m (69 ft 0.0 in); wing area 29.82 m2 (321.0 sq ft) **Fuselage:** length 4.57 m (15 ft 0.0 in), height 1.52 m (5 ft 0.0 in) **Powerplant:** one 8.45 kN (1,900 lb st) Williams International F129 (FJ44) turbofan **Weights:** maximum payload 454 kg (1,000 lb); maximum take-off weight 3901 kg (8,600 lb) **Fuel:** maximum fuel load 1,361 kg (3,000 lb) **Speed:** cruising speed 300 kts (556 km/h; 345 mph) **Range:** operational radius 1,000 n miles (1,852 km; 1,151 miles)

McDonnell Douglas EF-18 Hornet

Wing: span 44ft 8.5 in (13.62m); width folded 30 ft 7.25 in (9.32 m); aspect ratio 3.51; area 500.00 sq ft (46.45 m2) **Fuselage and tail:** length 60 ft 1.25 in (18.31 m); height 15 ft 9.5 in (4.82 m) **Powerplant:** two General Electric F414-GE-400 turbofans each rated at 22,000 lb st (97.86 kN) with afterburning **Weights:** empty 30,600 lb (13880 kg); maximum take-off 66,000 lb (29937 kg) **Fuel and load:** internal fuel 14,400 lb (6531 kg); external fuel up to 9,780 lb (4436 kg) in three 480-US gal (1818-liter) fuel tanks **Speed:** maximum level speed 'clean' at high altitude more than 1,033 kt (1,190 mph; 1915 km/h) **Range:** combat radius 591 nm (681 miles; 1095 km) on a hi-hi-hi mission **Performance:** combat ceiling about 50,000 ft (15240 m)

Boeing/Grumman E-8A

Wing: span 145 ft 9 in (44.42 m); aspect ratio 7.056; area 3,050.00 sq ft (283.35 m2) **Fuselage and tail:** length 152 ft 11 in (46.61 m); height 42 ft 5 in (12.93 m); tailplane span 45 ft 9 in (13.94 m); wheel track 22 ft 1 in (6.73 m); wheel base 17.98 m (59 ft 0 in) **Powerplant:** four Pratt & Whitney JT3D-7 each rated at 19,000 lb (84.52 kN) dry **Weights:** maximum take-off 333,600 lb (151315 kg) **Fuel and load:** internal fuel 159,560 lb (72375 kg); external fuel none; maximum theoretical payload 96,126 lb (43603 kg) **Speed:** maximum cruising speed at 25,000 ft (7620 m) 525 kt (605 mph; 973 km/h); economical cruising speed at 35,000 ft (10670 m) 464 kt (534 mph; 860 km/h) **Range:** range with maximum fuel 5,000 nm (5,758 miles; 9266 km) **Performance:** maximum rate of climb at sea level 4,000 ft (1219 m) per minute; service ceiling 39,000 ft (11890 m)

Ilyushin A-50 'Mainstay'

Wing: span 50.50 m (165 ft 8 in); aspect ratio 8.5; area 300.00 m (3,229.28 sq ft) **Fuselage and tail:** length 46.59 m (152 ft 10.25 in); height 14.76 m (48 ft 5 in); rotodome diameter 9.00 m (29 ft 6 in) **Powerplant:** four PNPP 'Aviadvigatel' (Soloview) D-30KP each rated at 117.68 kN (26,455 lb st) dry **Weights:** maximum take off 170000 kg (374,780 lb) **Fuel and load:** internal fuel about 81830 liters (21,617 US gal); external fuel none, but provision for inflight refueling **Speed:** maximum speed at optimum altitude 800 km/h (432 kt: 497 mph) **Range:** ferry range 6700 km (3,617 nm; 4,163 miles); range approx 5000 km (2,698 nm; 3,107 miles) **Performance:** absolute ceiling about 15500 m (50, 855 ft); take-off run 850 m (2,790 ft) at maximum take- off weight; landing run 450m (1,475 ft) at normal landing weight

Boeing/Sikorsky RAH-66 Comanche

Rotor system: main rotor diameter 39 ft 0.5 in (11.90 m); fantail rotor diameter 4 ft 6 in (1.37 m); main rotor disc area 1,197.14 sq ft (111.21 m2); fantail rotor disc area 15.90 sq ft (1.48 m2) **Fuselage and tail:** length overall, rotor turning 46 ft 10.25 in (14.28 m) and fuselage 43 ft 4.5 in (13.22 m) excluding gun barrel; height overall 11 ft 1.5 in (3.39 m) over stabilizer; stabilizer span 9 ft 3 in (2.82 m) **Powerplant:** two LHTEC T800-LHT-800 each rated at 1,344 shp (1002 kW) **Weights:** empty equipped 9,187 lb (4,167 kg); normal take-off 10,112 lb (4587 kg); maximum take-off 17,174 lb (7790 kg) **Fuel and load:** internal fuel 260 US gal (984 liters); external fuel up to two 460-US gal (1741.5-liter) auxiliary tanks **Speed:** maximum level speed 'clean' at optimum altitude 177 kt (204 mph; 328 km/h) **Range:** ferry range 1,260 nm (1,451 miles; 2335 km) with external fuel; endurance 2 hours 30 minutes **Performance:** maximum vertical rate of climb at sea level 1,182 ft (328 m) per minute **g limits:** -1 to +3.5

Helicopters

McDonnell Douglas Helicopters AH-64A Apache

Rotor system: main rotor diameter 48 ft 0 in (14.63 m); tail rotor diameter 9 ft 2 in (2.79 m); main rotor disc area 1,809.56 sq ft (168.11 m2); tail rotor disc area 70.00 sq ft (6.13 m2) **Wing:** span 17 ft 2 in (5.23 m) clean or 19 ft 1 in (5.82 m) over empty weapon racks **Fuselage and tail:** length overall, rotors turning 58 ft 3.125 in (17.76 m) and fuselage 49 ft 1.5 in (14.97 m); height overall 15 ft 3.5 in (4.66 m) to top of air data sensor, 14 ft 1.25 in (4.30 m) over turning tail rotor and 12 ft 7 in (3.84 m) to top of rotor head; stabilizer span 11 ft 2 in (3.40 m); wheel track 6 ft 8 in (2.03 m); wheel base 34 ft 9 in (10.59 m) **Powerplant:** two 1,696-shp (1265-kW) General Electric T700-GE-701 turboshafts each derated for normal operations or, from 604th helicopter, two General Electric T700-GE-701C turboshafts each rated at 1,800 shp (1342 kW) **Weights:** empty 11,387 lb (5165 kg); normal take-off 14,445 lb (6552 kg) at primary mission weight or 17,650 lb at design mission weight; maximum take-off 21,000 lb (9525 kg) **Fuel and load:** internal fuel 2,550 lb (1157 kg); maximum ordnance 1,700 lb (771 kg) **Speed:** never exceed speed 197 kt (227 mph; 365 km/h); maximum level speed 'clean' and maximum cruising speed at optimum altitude 158 kt (182 mph; 293 km/h) **Range:** ferry range 918 nm (1,057 miles; 1701 km) with drop tanks; range 260 nm (300 miles; 428 km) with internal fuel; endurance 3 hours 9 minutes with internal fuel **Performance:** max. vertical rate of climb at sea level 2,500 ft per minute; service ceiling 21,000 ft; hovering ceiling 15,000 ft in ground effect and 11,500 ft out of ground effect **g limits:** -0.5 to +3.5

Sikorsky S-70A (UH-60A Black Hawk)

Powerplant: two General Electric T700-GE-700 turboshafts each rated at 1,560 shp (1151 kW) or, in export helicopters, two General Electric T700-GE-701A turboshafts each rated at 1,723 shp (1285 kW) **Rotor system:** main rotor diameter 53 ft 8 in (16.36 m); tail rotor diameter 11 ft 0 in (3.35 m); main rotor disc area 2,262.03 sq ft (210.14 m2); tail rotor disc area 95.03 sq ft (8.83 m2) **Fuselage and tail:** length overall, rotors turning 64 ft 10 in, fuselage 50 ft 0.75 in and with rotors and tail pylon folded 41 ft 4 in ; height overall 16 ft 10 in with tail rotor turning, to top of rotor head 12 ft 4 in and in air-transportable configuration 8 ft 9 in; stabilizer span 14 ft 4.5 in ; wheel track 8 ft 10.5 in (2.705 m); wheel base 28 ft 11.75 in (8.83 m) **Weights:** empty 11,284 lb (5118 kg); normal take-off 16,994 lb (7708 kg); maximum take-off 20,250 lb (9185 kg) **Fuel and load:** internal fuel 360 US gal (1361 liters) plus provision for 370 US gal (1400 liters) of auxiliary fuel in two fuselage tanks; external fuel up to two 230-US gal (870-liter) and/or two 450-US gal (1703-liter) tanks; maximum payload 2,640 lb (1197 kg) carried internally or 8,000 lb (3629 kg) carried externally **Speed:** max. level speed 'clean' at sea level 160 kt; maximum cruising speed at 4,000 ft 145 kt; economical (single-engine) cruising speed at 4,000 ft 105 kt **Range:** ferry range 1,200 nm (1,382 miles; 2224 km) with four external auxiliary tanks; range 319 nm (368 miles; 592 km) with standard fuel; endurance 2 hours 18 minutes **Performance:** maximum vertical rate of climb at 4,000 ft 411 ft (125 m) per minute; service ceiling 19,000 ft; hovering ceiling 9,500 ft in ground effect and 10,400 ft out of ground effect

Boeing Vertol CH-47D Chinook

Rotor system: rotor diameter, each 60 ft 0 in (18.29m); rotor disc area, total 5,654.86 sq ft (525.34 m2) **Fuselage and tail:** length overall, rotors turning 98 ft 10.75 in (30.14 m) and fuselage 51 ft 0 in (15.54 m); height 18 ft 11 in (5.77 m) to top of rear rotor head; wheel track 10 ft 6 in (3.20 m); wheel base 22 ft 6 in (6.86 m) **Powerplant:** two Textron Lycoming T55-L-712 each rated at 3,750 shp (2796 kW) for take-off and 3,000 shp (2237 kW) for continuous running, or two Textron Lycoming T55-L-712 SSB each rated at 4,378 shp (3264 kW) for take-off and 3,137 shp (2339 kW) for continuous running, in both cases driving a transmission rated at 7,500 shp (5593 kW) on two engines and 4,600 shp (3430 kW) on one engine **Weights:** empty 22,379 lb (10151 kg); normal take-off 46,000 lb (20866 kg); maximum take-off 50,000 lb (22679 kg) **Fuel and load:** internal fuel 1,030 US gal (3899 liters); external fuel none; maximum payload 22,798 lb (10341 kg) **Speed:** maximum level speed at sea level 161 kt (185 mph; 298 km/h); maximum cruising speed at optimum altitude 138 kt (159 mph; 256 km/h) **Range:** ferry range 1,093 nm; operational radius between 100 and 30 nm with maximum internal and maximum external payloads respectively **Performance:** maximum rate of climb at sea level 2,195 ft per minute; service ceiling 22,100 ft (6735 m); hovering ceiling 10,550 ft (3215 m)

Sikorsky S-80 (CH-53E Super Stallion)

Rotor system: main rotor diameter 79 ft 0 in (24.08 m); tail rotor diameter 20 ft 0 in (6.10 m); main rotor disc area 4,901.67 sq ft (455.38 m2); tail rotor disc area 314.16 sq ft **Fuselage and tail:** length overall, rotors turning 99 ft 0.5 in (30.19 m), fuselage 73 ft 4 in (22.35 m), and overall with rotor and tail pylon folded 60 ft 6 in (18.44 m); height overall, rotors turning 29 ft 5 in (8.97 m), to top of rotor head 17 ft 5.5 in (5.32 m), and overall with rotor and tail pylon folded 18 ft 7 in (5.66 m); wheel track 13 ft 0 in (3.96 m); wheel base 27 ft 3 in (8.31 m) **Powerplant:** three General Electric T64-GE-416 turboshafts each rated at 4,380 shp for 10 minutes, 4,145 shp for 30 minutes and 3,696 shp (2756 kW) for continuous running **Weights:** empty 33,338 lb (15072 kg); maximum take-off 69,750 lb (31640 kg) with an internal payload or 73,500 lb (33340 kg) with an external payload **Fuel and load:** internal fuel 1,017 US gal (3849 liters); external fuel up to two 650-US gal (2461-liter) drop tanks; maximum payload 36,000 lb (16330 kg), or 30,000 lb (13607 kg) carried internally over a 100-nm (115-mile; 185-km) radius or 32,000 lb (14515 kg) carried externally over a 50-nm (57-mile; 92.5-km) radius **Speed:** maximum level speed 'clean' at sea level 170 kt (196 mph; 315 km/h); cruising speed at sea level 150 kt (173 mph; 278 km/h) **Range:** ferry range 1,120 nm (1,290 miles; 2075 km) without flight refueling; operational radius 500 nm (575 miles; 925 km) with 20,000-lb (9072-kg) external payload or 50 nm (57.5 miles; 92.5 km) with 32,000-lb (14515-kg) external payload **Performance:** max. rate of climb at sea lvl. with 25,000-lb payload 2,500 ft per minute; service ceiling 18,500 ft; hovering ceiling. 11,550 ft in ground effect and 9,500 ft out of ground effect

Helicopters

Mil Mi-28 'Havoc-A'

Rotor system: main rotor diameter 17.20 m (56 ft 5 in); tail rotor diameter 3.84 m (12 ft 7.25 in); main rotor disc area 232.35 m2 (2,501.10 sq ft); tail rotor disc area 11.58 m2 (124.66 sq ft) **Wing:** span 4.87 m (16 ft 0 in) **Fuselage and tail:** length overall, rotors turning 19.15 m (62 ft 10 in) and fuselage 16.85 m (55 ft 3.5 in); wheel track 2,29 m (7 ft 6.25 in); wheel base 11.00 m (36 ft 1 in) **Powerplant:** two Klimov (Isotov) TV3-117 turboshafts each rated at 1640 kW (2,200 shp) **Weights:** empty 7000 kg (15,432 lb); maximum take-off 10400 kg (22,928 lb) **Fuel and load:** internal fuel about 1900 liters (502 US gal); maximum ordnance about 1920 kg (4,233 lb) **Speed:** maximum level speed 'clean' at optimum altitude 300 km/h (162 kt; 186 mph); maximum cruising speed at optimum altitude 270 km/h (146 kt; 168 mph) **Range:** 470 km (253 nm; 292 miles) with standard fuel; endurance 2 hours 0 minutes **Performance:** service ceiling 5800 m (19,025 ft); hovering ceiling 3600 m (11,810 ft) out of ground effect

Mil Mi-24D 'Hind-D'

Rotor system: main rotor diameter 17.30 m (56 ft 9 in); tail rotor diameter 3.908 m (12 ft 10 in); main rotor disc area 235.00 m2 (2,529.52 sq ft); tail rotor disc area 11.99 m2 **Wing:** span 6.536 m (21 ft 5.5 in) **Fuselage and tail:** length overall, rotors turning 19.79 m (64 ft 11 in) and fuselage 17.51 m (57 ft 5.5 in) excluding rotors and gun; height overall 6.50 m (21 ft 4 in) with rotors turning and 4.44 m (14 ft 6.75 in) to top of rotor head; stabilizer span 3.27 m (10 ft 9 in); wheel track 3.03 m (9 ft 11.5 in); wheel base 4.39 m (14 ft 5 in) **Powerplant:** two Klimov (Isotov) TV3-117 Series III turboshafts each rated at 1640 kW (2,200 shp) **Weights:** empty 8400 kg (18,519 lb); normal take-off 11000 kg (24,250 lb); maximum take-off 12500 kg (27,557 lb) **Fuel and load:** internal fuel 1500 kg (3,307 lb) or 2130 liters (563 US gal) plus provision for 1000 kg (2,205 lb) or 850 liters (225 US gal) of auxiliary fuel in a cabin tank; external fuel (instead of internal auxiliary tank) up to 1200 kg (2,646 lb) in four 500-liter (132-US gal) drop tanks; maximum ordnance 2400 kg (5,291 lb) **Speed:** maximum level speed 'clean' at optimum altitude 310 km/h (168 kt; 192 mph); maximum cruising speed at optimum altitude 260 km/h (140 kt; 162 mph)**Range:** 750 km (405 nm; 466 miles) with internal fuel; combat radius 160 km (86 nm; 99 miles) with maximum military load, or 250 km (135 nm; 155 miles) with two drop tanks, or 288 km (155 nm; 179 miles) with four drop tanks Performance**:** maximum rate of climb at sea level 750 m (2,461 ft) per minute; service ceiling 4500 m (14,765 ft); hovering ceiling 2200 m (7,220 ft) out of ground effect

Mil Mi-26 'Halo-A'

Rotor system: main rotor diameter 32.00 m (105 ft 9 in); tail rotor diameter 7.61 m (24 ft 11.5 in); main rotor disc area 804.25 m2 (8,657.13 sq ft); tail rotor disc area 45.48 m2 (489.60 sq ft) **Fuselage and tail:** length overall, rotors turning 40.025 m (131 ft 3.75 in) and fuselage 33.727 m (110 ft 8 in) excluding tail rotor; height overall 8.145 m (26 ft 8.25 in) to top of rotor head; wheel track 7.17 m (23 ft 6.25 in); wheel base 8.95 m (29 ft 4.5 in) **Powerplant:** two ZMDB 'Progress' (Lotarev) D-136 turboshafts each rated at 8380 kW (11,240 shp) **Weights:** empty 28200 kg (62,170 lb); normal take-off 49600 kg (109,347 lb); maximum take-off 56000 kg (123,457 lb) **Fuel and load:** internal fuel 12000 liters (3,170 US gal); external fuel none; maximum payload 20000 kg (44,092 lb) **Speed:** maximum level speed at optimum altitude 295 km/h (159 kt; 183 mph); normal cruising speed at optimum altitude 255 km/h (137 kt; 158 mph) **Range:** ferry range 2000 km (1,080 nm; 1,240 miles) with auxiliary fuel; range 800 km (432 nm; 497 miles) with standard fuel **Performance:** service ceiling 4600 m (15,090 ft); hovering ceiling 1800 m (5,905 ft) out of ground effect

Kamov Ka-50 Werewolf 'Hokum'

Rotor system: rotor diameter, each 14.50 m (45 ft 6.9 in); rotor disc area, total 330.26 m2 (3,555.00 sq ft) **Fuselage and tail:** length overall, with rotors turning 16.00 m (52 ft 5.9 in), and fuselage excluding probe and gun 13.50 m (44 ft 3.5 in); height 5.40 m (17 ft 8.6 in) **Powerplant:** two Klimov (Isotov) TV3-117VK turboshafts each rated at 1660 kW (2,226 shp) **Weights:** maximum take-off 7500 kg (16,534 lb) **Speed:** maximum level speed 'clean' at optimum altitude 350 km/h (188 kt; 217 mph) **Range:** combat radius about 250 km (135 nm; 155 miles) **Performance:** maximum vertical rate of climb at 2500 m (8,200 ft) 600 m (1,969 ft) per minute; hovering ceiling 4000 m (13,125 ft) out of ground effect

Transport Aircraft

McDonnell Douglas C-17A Globemaster III

Wing: span 165 ft 0 in (50.29 m) basic and 171 ft 3 in (52.20 m) between winglet tips; aspect ratio 7.16; area 3,800.00 sq ft (353.02 m2) **Fuselage and tail:** length 174 ft 0 in (53.04 m); height 55 ft 1 in (16.79 m); tailplane span 65 ft 0 in (19.81 m); wheel track 33 ft 8.5 in (10.27 m); wheel base 65 ft 9.5 in (20.05 m) **Powerplant:** four Pratt & Whitney F117-P-100 turbofans each rated at 41,700 lb st (185.49 kN) **Weights:** operating empty 269,000 lb (122016 kg); maximum take-off 580,000 lb (263083 kg) **Fuel and load:** internal fuel 27,108 US gal (102614 liters); maximum payload 172,200 lb (78108 kg); typical payload 124,000 lb (56245 kg) on an inter-theatre logistics mission at a 2.25-g load factor increasing to 153,300 lb (69535 kg) on a heavy logistics mission at a 2.5-g load factor. **Speed:** maximum cruising speed at low altitude 350 kt CAS; airdrop speed at sea level between 115 and 250 kt; or at 25,000 ft between 130 and 250 kt **Range:** ferry range with maximum fuel and no payload 4,700 nm (5,412 miles; 8710 km); range with a 124,000-lb (56245-kg) payload 2,800 nm (3,225 miles; 5190 km), or with a 158,500-lb (71895-kg) payload 2,700 nm (3,110 miles; 5000 km), or with a 160,000-lb (72575-kg) payload 2,400 nm (2,765 miles; 4445 km); radius with an 81,100-lb (36786-kg) payload 500 nm (575 miles; 925 km) or with a 124,000-lb (56245-kg) payload 1,900 nm (2,190 miles; 3520 km) **Performance:** service ceiling 45,000 ft; take-off field length with 167,000-lb payload 7,500 ft; landing field length with 167,000-lb payload 3,000 ft (914 m) with thrust reversal

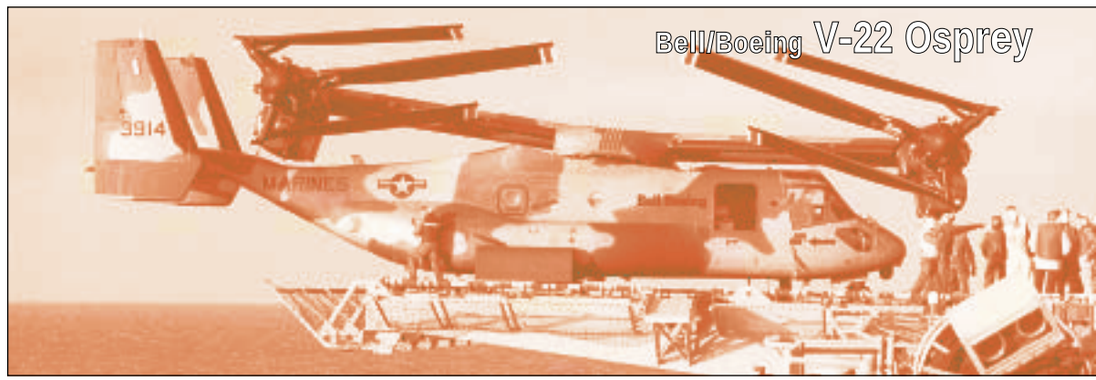
Lockheed C-130J Hercules II

Wing: span 132 ft 7 in (40.41 m); aspect ratio 10.01; area 1,745.00 sq ft (161.12 m2) **Fuselage and tail:** length 97 ft 9 in (29.79 m); height 38 ft 10 in (11.84 m); tailplane span 52 ft 8 in (16.05 m); wheel track 14 ft 3 in (4.35 m); wheel base 32 ft 0.75 in (9.77 m) **Powerplant:** four Allison AE2100D3 turboprops flat rated to 4,591 ehp (3,424 kW) **Weights:** empty equipped 69,300 lb (31434 kg); maximum take-off 135,000 lb (61236 kg) **Fuel and load:** internal fuel 6,750 US gal (25,552 liters); maximum payload 41,790 lb (18,955 kg) **Speed:** maximum cruising speed at 30,000 ft (9145 m) 348 kt (400 mph; 645 km/h) **Range:** range 4,210 nm (4,848 miles; 7802 km) with maximum fuel or 2,835 nm (3,262 miles; 5,250 km) with maximum payload **Performance:** maximum rate of climb at sea level 2,100 ft (640 m) per minute; service ceiling 34,000 ft (10365 m); take-off distance to 50 ft (15 m) 4,700 ft (1433 m) at maximum take-off weight

Lockheed C-5B Galaxy

Wing: span 222 ft 8.5 in (67.88 m); aspect ratio 7.75; area 6,200.00 sq ft (575.98 m2) **Fuselage and tail:** length 247 ft 10 in (75.54 m); height 65 ft 1.5 in (19.85 m); tailplane span 68 ft 8.5 in (20.94 m); wheel track 37 ft 5.5 in (11.42 m); wheel base 72 ft 11 in (22.22 m) **Powerplant:** four General Electric TF39-GE-1C turbofans each rated at 43,000 lb st (191.27 kN) **Weights:** operating empty 374,000 lb (169643 kg); maximum take-off 837,000 lb (379657 kg) **Fuel and load:** internal fuel 332,500 lb (150815 kg); external fuel none; maximum payload 261,000 lb (118387 kg) **Speed:** never exceed speed 402 kt (463 ph; 745 km/h) CAS; maximum level speed at 25,000 lb (7620 m) 496 kt (571 mph; 919 km/h); maximum cruising speed at 25,000 lb (7620 m) between 460 and 480 kt (552 and 564 mph; 888 and 908 km/h); economical cruising speed at 25,000 ft (7,620 m) 450 kt (518 mph; 833 km/h) **Range:** 5,618 nm (6,469 miles; 10411 km) with maximum fuel or 2,982 nm (3,434 miles; 5526 km) with maximum payload **Performance:** maximum rate of climb at sea level 1,725 ft (525 m) per minute; service ceiling 35,750 ft (10895 m) at 615,000 lb (278960 kg); take-off run 8,300 ft (2530 m) at maximum take-off weight; take-off distance to 50 ft (15 m) 9,800 ft (2987 m) at maximum take-off weight; landing distance from 50 ft (15 m) 3,820 ft (1164 m) at maximum landing weight; landing run 2,380 ft (725 m) at maximum landing weight

Bell/Boeing V-22 Osprey

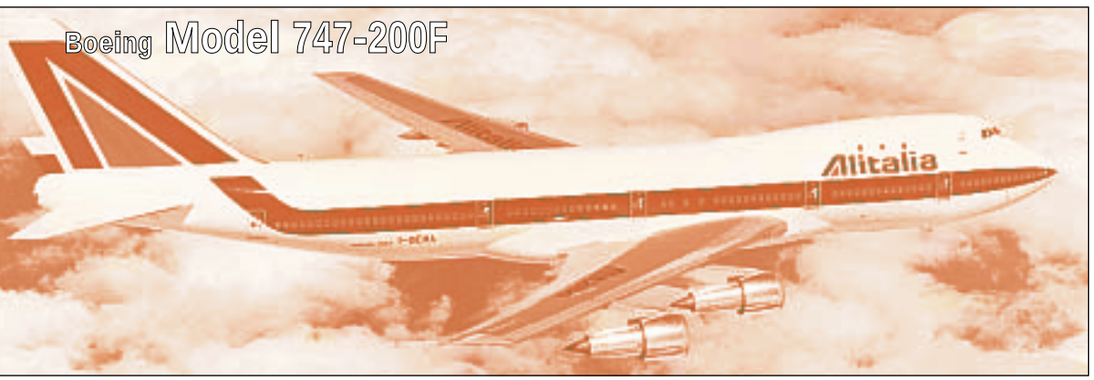


Wing and rotors: rotor diameter, each 38 ft 0 in; width overall, rotors turning 84 ft 6.8 in and with rotors folded 18 ft 5 in; rotor disc area, total 2,268.23 sq ft (210.72 m2) **Wing:** span 50 ft 11 in (15.52 m) including nacelles; aspect ratio 6.77; area 382.00 sq ft (35.59 m2) **Fuselage and tail:** length, fuselage excluding probe 57 ft 4 in (17.47 m); height over fins 17 ft 7.8 in (5.38 m) and overall with nacelles vertical 20 ft 10 in (6.35 m); tailplane span over fins 18 ft 5 in (5.61 m); wheel track 15 ft 2 in (4.62 m); wheel base 21 ft 7.5 in (6.59 m) **Powerplant:** two Allison T406-AD-400 each rated at 6,150 shp (4586 kW) for take-off and 5,890 shp (4392 kW) for continuous running **Weights:** empty equipped 31,886 lb (14463 kg); normal mission take-off 47,500 lb (21545 kg) for VTO and 55,000 lb (24947 kg) for STO; maximum take-off 60,500 lb for STO **Fuel and load:** internal fuel 13,700 lb (6215 kg) standard and 30,074 lb (13641 kg) with self-ferry cabin tanks; maximum internal payload 20,000 lb (9072 kg); maximum external payload 10,000 lb (4536 kg) on a hook or 15,000 lb (6804 kg) on two hooks **Speed:** maximum cruising speed at optimum altitude 300 kt (345 mph; 556 km/h) in aeroplane mode; maximum cruising speed at sea level 100 kt (115 mph; 185 km/h) in helicopter mode and 275 kt (316 mph; 509 km/h) in aeroplane mode; maximum forward speed with maximum slung load 200 kt (230 mph; 370 km/h) **Range:** ferry range 2,100 nm (2,418 miles; 3892 km) after STO at 60,500 lb (27442 kg); tactical range 1,200 nm (1,382 miles; 2224 km) after VTO at 44,619 lb (21146 kg) with 12,000-lb (5443-kg) payload, or 1,800 nm (2,075 miles; 3336 km) after STO at 55,000 lb (24947 kg) with 20,000-lb (9072-kg) payload **Performance:** service ceiling 26,000 ft (7925 m); take-off run less than 500 ft (152 m) at normal STO weight

Ilyushin Il-76MF 'Candid'

Wing: span 50.50 m (165 ft 8 in); aspect ratio 8.5; area 300.00 m2 (3,229.28 sq ft) **Fuselage and tail:** length 53.19 m (174 ft 6 in); height 14.45 m (47 ft 5 in) **Powerplant:** four Aviadvigatel PS-90AN turbofans each rated at 156.9 kN (35,275 lb st) dry **Weights:** maximum take-off 190000 kg (481,871 lb) **Fuel and load:** internal fuel about 81830 liters (21,617 US gal); external fuel none; maximum payload 48000 kg (105,820 lb) **Speed:** maximum level speed 'clean' at optimum altitude 850 km/h (459 kt; 528 mph); cruising speed between 9000 and 12000 m (29,530 and 39,370 ft) between 750 and 800 km/h (405 and 432 kt; 466 and 497 mph) **Range:** ferry range 7900 km (4,263 nm; 4,909 miles); range 5000 km (2,698 nm; 3,107 miles) with maximum payload **Performance:** absolute ceiling about 15500 m (50,855 ft); take-off run 850 m (2,790 ft) at maximum take-off weight; landing run 450 m (1,475 ft) at normal landing weight

Boeing Model 747-200F



Wing: span 195 ft 8 in (59.64 m); aspect ratio 7.0; area 5,500.00 sq ft (510.95 m2) **Fuselage and tail:** length 231 ft 10 in (70.66 m); height 63 ft 5 in (19.33 m); tailplane span 72 ft 9 in (22.17 m); wheel track 36 ft 1 in (11.00 m); wheel base 84 ft 0 in (25.60 m) **Powerplant:** four Pratt & Whitney JT9D-7R4G2 each rated at 54,750 lb st (243.54 kN) dry, or General Electric CF6-50E2 (F103-GE-102) each rated at 52,500 lb st (233.53 kN) dry, or General Electric CF6-80C2 each rated at 56,700 lb st (252.21 kN) dry, or Rolls-Royce RB211-524D4-B each rated at 53,110 lb st (236.24 kN) dry Weights: operating empty 342,200 lb (155219 kg) with JT9D engines, or 345,700 lb (156807 kg) with CF6-50 engines, or 348,300 lb (157986 kg) with CF6-80 engines, or 351,100 lb (159256 kg) with RB211 engines; maximum take-off 775,000 lb (351525 kg) with options at 785,000 lb (356070 kg), 800,000 lb (362875 kg), 820,000 lb (371945 kg) and 833,000 lb **Fuel and load:** internal fuel 364,400 lb (165289 kg) with JT9D and RB211 engines, or 361,870 lb (164141 kg) with both CF6 engine variants; external fuel none; maximum payload 247,800 lb (112400 kg) with JT9D , or 244,300 lb (110812 kg) with CF6-50, or 348,300 lb (109633 kg) with CF6-80, or 238,900 lb (108363 kg) with RB211 **Speed:** maximum level speed 'clean' at 30,000 ft (9145 m) between 522 and 530 kt (601 and 610 mph; 967 and 981 km/h) depending on engine type. **Range:** ferry range 7,900 nm with JT9D engines, or 7650 nm with CF6-50 engines, or 8,300 nm; with CF6-80 engines, or 7,950 nm; range with a 200,000-lb payload 4,700 nm; 8704 with JT9D engines, or 4,550 nm with CF6-50 engines, or 4,900 nm with CF6-80 engines, or 4,650 nm ; 8612 km) with RB211 engines

Boeing Model 767-200

Wing: span 156 ft 1 in (47.57 m); aspect ratio 7.9; area 3,050.00 sq ft (283.35 m2) **Fuselage and tail:** length 159 ft 2 in (48.51 m); height 52 ft 0 in (15.85 m); tailplane span 61 ft 1 in (18.62 m); wheel track 30 ft 6 in (9.30 m); wheel base 64 ft 7 in (19.69 m) **Powerplant:** typically two Pratt & Whitney JT9D-7R4D or General Electric CF6-80A each rated at 48,000 lb st (213.51 kN) dry **Weights:** manufacturer's empty 164,800 lb (74752 kg) with JT9D engines or 163,900 lb (74344 kg) with CF6 engines; operating empty 178,400 lb (80921 kg) with JT9D engines or 177,500 lb (80512 kg) with CF6 engines; maximum take-off 300,000 lb (136078 kg) **Fuel and load:** internal fuel 112,725 lb (51131 kg); external fuel none; maximum payload 43,200 lb (19595 kg) **Speed:** maximum cruising speed at optimum altitude Mach 0.80 **Range:** range 3,160 nm (3,639 miles; 5856 km) with JT9D engines or 3,220 nm (3,708 miles; 5967 km) with CF6 engines **Performance:** initial cruise ceiling 39,200 ft (11950 m) with JT9D engines or 39,700 ft (12100 m) with CF6 engines; take-off field length 5,900 ft (1798 m) at max. take-off weight

Learjet 35A

Wing: span 39 ft 6 in (12.04 m) with tip tanks; aspect ratio 5.7; area 253.3 sq ft (23.53 m2) **Fuselage and tail:** length 48 ft 8 in (14.83 m); height 12 ft 3 in (3.73 m); tailplane span 14 ft 8 in (4.47 m); wheel track 8 ft 3 in (2.51 m); wheel base 20 ft 2 in (6.15 m) **Powerplant:** two Garrett TFE731-2-2B turbofans each rated at 3,500 lb st (15.57 kN) **Weights:** empty equipped 9,838 lb (4462 kg); maximum take-off 18,300 lb (8301 kg) **Fuel and load:** internal fuel 931 US gal (3524 liters); external fuel none; maximum payload 3,500 lb (1588 kg) **Speed:** never exceed speed Mach 0.83; maximum level speed at 25,000 ft (7620 m) 471 kt (542 mph; 872 km/h); maximum cruising speed at 41,000 ft (12495 m) 460 kt (529 mph; 851 km/h); economical cruising speed at 45,000 ft (13715 m) 418 kt (481 mph; 774 km/h) **Range:** range 2,289 nm (2,634 miles; 4,239 km) with four passengers **Performance:** maximum rate of climb at sea level 4,340 ft (1323 m) per minute; service ceiling 45,000 ft (13715 m); take-off balanced field length 4,972 ft (1515 m) at 18,300 lb (8301 kg); landing run 3,075 ft (937 m) at maximum landing weight

Boeing KC-135R Stratotanker

Wing: span 130 ft 10 in (39.88 m); aspect ratio 7.04; area 2,433.00 sq ft (226.03 m2) **Fuselage and tail;** length 136 ft 3 in (41.53 m); height 41 ft 8 in (12.70 m); tailplane span 40 ft 3 in (12.27 m); wheel base 46 ft 7 in (14.20 m) **Powerplant:** four CFM International F108-CF-100 each rated at 22,000 lb st (97.86 kN) dry **Weights:** operating empty 106,306 lb (48220 kg): maximum take-off 322,500 lb (146284 kg) **Fuel and load:** internal fuel 203,288 lb (92210 kg); maximum payload 83,000 lb (37650 kg) **Range:** ferry range 7,990 nm (9,200 miles; 14806 km);operational radius 2,500 nm (2,879 miles; 4633 km) to offload 150 per cent more fuel than the KC-135A **Performance:** maximum rate of climb at sea level 1,290 ft (393 m) per minute; service ceiling 45,000 ft (13715 m); typical take-off run 10,700 ft (3261 m) increasing to 14,000 ft (4267 m) under 'hot and high' conditions at maximum take-off weight

Ilyushin IL II-78M 'Midas'

Wing: span 50.50 m (165 ft 8 in): aspect ratio 8.5: area 300.00 m2 (3,229.28 sq ft) **Fuselage and tail:** length 46.59 m (152 ft 10.25 in); height 14.76 m (48 ft 5 in) **Weights:** maximum take off 170000 kg (374,780 lb)Fuel and load: internal fuel about 81830 liters (21,617 US gal) for own use **Speed:** maximum level speed 'clean' at optimum altitude 850 km/h (459 kts; 528 mph); cruising speed between 9000 and 12000 m (29,530 and 39,370 ft) between 750 and 800km/h (405 and 432 kt; 466 and 497 mph) **Range:** ferry range 6700 km (3,617 nm; 4,163 miles); range 5000 km (2,698 nm; 3,107 miles) with maximum payload **Performance:** absolute ceiling about 15500 m (50,855 ft); take-off run 850 m (2,790 ft) at maximum take-off weight; landing run 450 m (1,475 ft) at normal landing weight

A

AA or A-A Air-to-Air.

AAA - Or 'Triple A' Anti Aircraft Artillery.

AAM Air-to-Air Missile.

AA-10 Alamo NATO designation for the R-27.

AA-11 Archer NATO designation for the R-73 IR missile.

AA-12 Adder NATO designation for the R-77 IR missile.

AAR Air-to-Air Refueling.

AAV Armored Amphibious Assault Vehicle.

AB AfterBurner.

AC Aircraft.

ACA Agile Combat Aircraft.

ACE Armored Combat Earth mover.

AC-GEN Aircraft generator.

ACM Air Combat Maneuvers.

ACRV Armored Command and Reconnaissance Vehicle.

AD Air Defense.

ADAM Area Denial Artillery Munitions.

ADATS Air Defense Anti-Tank System.

ADI Attitude Director Indicator.

AEW Airborne Early Warning.

AEV Armored Engineer Vehicle.

Afterburner Part of a jet engine that increases the power of the engine by burning fuel in the jet exhaust.

AG or A-G Air-to-Ground.

AGM Air-to-Ground Missile.

Aileron Control surface on an aircraft wing that produces aircraft roll.

AIM Air Intercept Missile.

AIR-BRK Air Brake.

AIR-FRM The Air Frame.

All-Aspect Weapons that are effective at any angle to the target.

ALT Altitude above sea level.

AMRAAM Advanced Medium Range Air-to-Air Missile.

AOA Angle of Attack.

AP Armor Piercing.

Approach Line-up prior to landing.

APC Armored Personnel Carrier.

APHE Armor-Piercing High Explosive.

ARM Anti-Radiation Missile.

ARMY Military Target .

ASARS Advanced Synthetic Aperture Radar System.

Aspect Angle The angle formed between the line of sight and the nose of the target aircraft.

ASW Anti-Submarine Warfare.

ASRAAM Advanced Short Range Air-to-Air Missile.

Attitude The state of an aircraft in terms of pitch, bank and yaw.

ATC Air Traffic Control.

ATF Advanced Tactical Fighter.

ATGW Anti Tank Guided Weapon.

ATM Air Tasking Message.

ATO Air Tasking Order

Auto-pilot A mode in which the flight control computer takes control of the aircraft.

AUX-POW Auxiliary Power.

AVI Avionics.

Avionics Electronic systems in the aircraft.

AWACS Airborne Warning And Control System.

B

BAI Battlefield Air Interdiction.

Bandit A known hostile aircraft.

Bank The angle of the wings about the longitudinal axis referenced to the horizontal.

Bank To roll the aircraft to one side and induce a turn.

BCOM Base Commander.

Beaming Flying perpendicular to the emissions from a threat radar.

BDA Bomb Damage Assessment.

BFM Basic Flight Maneuvers.

Bingo "Bingo Fuel" is the amount needed to return to base.

Blackout Loss of consciousness due to excessive forces on the pilot.

Blast-Fragmentation Warhead An explosive charge which creates a large amount of shrapnel.

BLU Bomb Live Unit.

Glossary

BMEWS Ballistic Missile Early Warning System.

Bogey An unknown aircraft. A Bogey becomes a bandit when identified as hostile.

Bracket An ACM tactic in which two (or more) aircraft fly opposite sides of a threat formation.

Break To suddenly turn in the hope that any enemy following will lose his tactical advantage.

Break-Through Pressure Pressure needed to overcome the G-limiter on the joystick.

Bug-Out Leave a dogfight.

BVR Beyond Visual Range.

C

C4 Command, Communications, Control & Computing Target.

CallSign A pilot's or controller's code name.

CAP Combat Air Patrol.

CAS Close Air Support.

CBU Cluster-Bomb Unit.

CEP Circular Error Probability (measure of bombing performance).

CFPD Command Flight Path Display System.

Chaff Packets of foil used to decoy or obscure radar systems.

COMMS The F-22's Communication Systems.

Compass Tape Heading indicator at the top of the HUD.

Concussive With violent, if not explosive, force.

Corner Velocity The velocity at which an aircraft achieves its best turn performance.

Continuous Wave Radar A system which emits radio waves continuously, as opposed to pulses (see PULSE DOPPLER RADAR).

Court Martial A military trial held when breaches of conduct codes occur.

CTOL Conventional Take-Off and Landing.

CS Control Surfaces.

D

DEF Defensive Target.

DEFCON DEFense CONdition. A series of alert conditions set which cause world wide forces to establish escalating levels of readiness and security.

DLIR Downward Looking InfraRed.

Dogfight Engaging enemy aircraft.

Doppler Radar Airborne radar which makes use of Doppler effect (frequency shift) in signals reflected from ahead and behind aircraft to give measure of speed over the ground and to distinguish moving targets.

Drogue Chute A parachute released to slow an aircraft, usually when landing.

Drag Factor A number which indicates how unaerodynamic external stores on an aircraft are.

Durandal Runway cratering missile.

E

ECCM Electronic Counter Counter Measures.

ECM Electronic Counter Measures.

Element Two aircraft working together as a team, possibly as an element of a larger flight.

Elevators Aircraft control surfaces, located at the back of the horizontal stabilizers, which provide pitching movement.

EO Electro-Optical.

EMCON EMission CONtrol level.

ENG Engine.

ERA Explosive Reactive Armor.

ESM Electronic Support Measures.

EW Electronic Warfare.

EW Radar Early Warning Radar.

F

FAB Fugasnaya Aviatsyonna Bomba, Russian designation for 'general purpose bomb'.

FAC Forward Air Controller.

FARP Forward Air Refueling Point.

FBW Fly-by-wire a flight control system which transmits flight commands via wires to servo actuators which drive the ailerons, rudders or other control surfaces. In most FBW systems, pilot input is processed and possibly negated by a flight computer before being sent to the control actuators.

FCC Fire Command Center.

FCS Fire Control System.

FCS Flight Control System.

FEBA Forward Edge of Battle Area.

Fire and forget A missile that once fired, will guide itself to its target.

Flak Shrapnel produced by AAA shells exploding.

Flame-out Stalling of aircraft engine due to adverse circumstances; e.g. bird-strike.

Flaps Control surfaces on aircraft wings which increase lift for a given flight condition and allow a lower airspeed than is normal in flight.

Flaperons A useful control surface which is a cross between ailerons and flaps.

Flares Pyrotechnic packages which burn with intense heat designed to confuse InfraRed missiles.

Flashpoint A trouble zone, be it economic, military or otherwise.

FLIR Forward Looking InfraRed

FOD Foreign Object Damage

Fuze An adjustable triggering device in a missile, bomb or other weapon

G

G, G Force A force acting upon the aircraft and pilot when maneuvering, expressed in terms of the earth's gravitational force.

GB Ground Based Target.

GBU Guided Bomb Unit.

GLCM Ground Launched Cruise Missile.

GLLD Ground Laser Locator Designator.

G-LOC G-induced Loss Of Consciousness.

GPS Global Positioning System.

G-suit A suit worn by pilots which reduces the effects of high G forces.

H

HARM High-speed Anti-Radiation Missile.

Hard target Target which is armored.

Hard points Weapons pylons for carrying anything except fuel (see WET POINTS).

HAS Hardened Aircraft Shelter.

HE High Explosive.

HEAT High Explosive Anti-Tank.

HE-FRAG High Explosive Fragmentation

HOTAS Hands On Throttle And Stick, which puts all controls at the pilot's fingertips.

HSI Horizontal Situation Indicator - a cockpit indicator which combines a compass with information from an inertial reference system or navigation beacons to indicate the relationship of the aircraft with the planned course.

HUD Head-Up Display.

HYD Hydraulic systems.

I

IFDL In Flight Data Link

IFF Identification Friend or Foe.

IIR Imaging InfraRed.

ILS Instrument Landing System.

IND Industrial Target.

INF Infrastructure Target.

Indicated airspeed The airspeed shown by an airspeed indicator and not corrected for error due to air density variations, caused by altitude and temperature.

INS Inertial Navigation System.

IR Infra-Red.

IRI Intermittent Radar Imaging.

IRD InfraRed Decoy.

IRSTS Infrared Search and Track. A system that tracks aircraft and missiles using the heat generated by their engines and by their friction with the air.

J

Jamming Confusing the enemy radar by using high-energy bursts of a certain frequency.

Glossary

JDAM Joint Direct Attack Munitions.
JSOW Joint Stand Off Weapon.
J-STARS Joint Surveillance Targeting And Reconnaissance System
JTACMS Joint Tactical Missile System.
JTIDS Joint Tactical Information Distribution System.

K

KC -135 Mid-air refueling tanker.
KIA Killed In Action.
Knock it off Slang for 'end the mission'.
KNOTS Nautical miles per hour.
KTAS Knots True Air Speed.
KIAS Knots Indicated Air Speed.
KTS Abbreviation for Knots.

L

LANTIRN Low Altitude Navigation and Targeting Infra- red Attack System for Night.
LGB Laser Guided Bomb.
Lizard A term often used to describe the enemy leader.
Load factor The force acting on an aircraft as a multiple of the force of gravity.
Lock Acquire a target and fix weapons aiming systems on it.
Loose cannon A renegade pilot.
LRMTS Laser Ranger and Marked Target Seeker.
LZ Landing Zone.

M

MACH Unit of speed equal to the speed of sound at your altitude.
MAS Maneuvering Attack System.
MAW Missile Approach Warning
MBT Main Battle Tank.
MEWS Mobile Electronic Warfare System.
MFD Multi-Function Display unit.
MIA Missing In Action.
MiG Mikoyan Gurevich - the founders of one of major Russian aircraft design bureaus.
MMD Moving map display used for navigation.
MMS Missile Management System.
MP Maritime Patrol.
MRM Medium Range Missile.

N

NATO North Atlantic Treaty Organization.
NAV Naval Target.
NM Nautical mile - 6,076 feet.
NAV Navigation.
NBC Nuclear, Biological, Chemical.
Negative G's G-force that forces you out of your seat.
NOE Nap Of the Earth, very low altitude.
NVE/NV Night Vision Equipment.
NWS Nose Wheel Steering.

O

Ordnance Bombs, missiles, bullets and other offensive hardware.
OS Offensive Support.
OTR Operational Turn-Round. Rapid re-arming and refuelling of combat aircraft.
OTH-B Over the Horizon Backscatter (radar).

P

Padlock Directs the pilot's view to a selected object.
PAVE TACK Targeting system for laser guided bombs
PGB Precision Guided Bomb.
Pincer As Bracket maneuver.
PIO Pilot Induced Oscillation - oscillation in an aircraft's flight path or attitude caused by a pilot failing to compensate for the lag time between pilot input and aircraft reaction.
Pipper A small dot at the centre of the aiming reticule.
PIT Political Target.
Pitch The angle of an aircraft's nose above or below the horizon.
Pitch ladder Pitch indicator in the HUD.
PK Probability of Kill.
POL Petrol, Oil & Lubricant Target.
Positive G's G-force that forces you into your seat.
Predictor sight A computerized gun sight that predicts the flight of cannon shells.
PRES Cockpit Pressure.
Pressure breathing Forced breathing to help cope with high G Maneuvers.
Pulse doppler radar Radar that emits short bursts of radio waves and detects objects by the returning echo.
Push 1 (Also known as STUD) Frequency setting on aircraft radio (similar to presets in a car radio).

R

Radar Radio Detection And Ranging.
RCS Radar Cross Section
Recce Reconnaissance.
Redout Effect felt by pilot when pushing negative G's for too long.
RHWR Radar Homing Warning Receiver.
RHAW Radar Homing and Warning.
RI Radar Imaging
RMG Ranging Machine Gun.
ROE Rules Of Engagement - rules governing the conditions under which a fighter can engage or fire upon an enemy.
Roll Rotation around an aircraft's longitudinal axis.
Rookie Inexperienced pilot.
RP Rocket Propelled.
RPM Revolutions Per Minute.
RSBN A radio navigation beacon.
RTB Return To Base.
Rudder Control surface on the tail of an aircraft which affects the yaw of aircraft.
RV Rendezvous.
RWR Radar Warning Receiver.
R-27 An advanced Russian AA radar-guided missile.
R-60 A second-generation Russian heat-seeking missile.
R-73 A third-generation Russian heat-seeking missile.

S

SA Strike/Attack.
SA Semi-Active. Refers to radar guided missile which requires the radar to illuminate the target all the way to the impact.
SA Situational Awareness, the amount of awareness a pilot has about the local tactical environment.
Sandwich maneuver (Also drag maneuver) Decoy maneuver to distract fighters away from their targets.
SAMs Surface-to-Air Missiles.
SAR Search and Rescue.
SARH Semi-Active Radar Homing.
SEAD Suppression of Enemy Air Defenses.
Semi-active Used to describe a missile which must be guided until its own radar can take over.
Sideslip Motion of an aircraft to the right or left perpendicular to its longitudinal axis.
Six o'clock Directly behind an aircraft, where it is most vulnerable.
SLAM Stand-off Land Attack Missile.
SLAR Side-Looking Airborne Radar.
Slats Extendible leading edge high lift devices.
SLIR Sideways-Looking InfraRed (system).
Soft target Target without any armor.
SRAM Short Range Attack Missile.
STALL Loss of control due to low airspeed or excessive Maneuvers at high altitude.
Statute mile 5,280 feet..
Stealth Ability to avoid detection.

T

TADS Target Acquisition and Designator System.
TCOM Theater Commander
TERPROM Terrain following system.
Terrain hugging Flying at 500 feet or below, following the contours of the land.
TFR Terrain Following Radar.

Glossary

Threat Any enemy in your vicinity.

Thrust Power produced by your engines, usually referred to as a percentage.

Thrust vectoring The ability to adjust the direction of thrust via movable nozzles.

TOT Time On Target

TOW Time On Waypoint

TRIM Setting aircraft controls or trim devices so that the aircraft maintains a desired attitude.

Trim tab A small control surface attached to an aileron of other larger control surface for the purpose of making small trim corrections to that surface's position.

True airspeed The actual speed at which the aircraft is travelling through the surrounding atmosphere.

TWS Track While Scan radar mode.

U

UND Under carriage.

V

VASI Visual Approach Slope Indicator system of lights for landing assistance.

Velocity vector An indicator in the HUD which shows predicted path of travel.

Vertical velocity The sink or climb rate of an aircraft.

Virtual cockpit True 3-D scrolling, panning cockpit.

VSI Vertical Speed Indicator.

V/STOL Vertical/Short Take-Off and Landing.

W

W-BAY Weapons Bay.

Waypoint A position in the world to which you have to fly.

WCS Weapon Control System.

Wet points Places on the plane where external fuel tanks can be mounted.

Wild weasel Anti SAM RADAR mission, specifically against enemy air defenses.

Wingman A flying partner.

Wire The correct flight path for weapon delivery.

WP WayPoint.

Y

Yaw Rotation of aircraft about its vertical axis.

Z

Zero-zero ejection Ejection at zero altitude and zero speed.

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With thanks to. . .

ALL THOSE RESPONSIBLE FOR THE DEVELOPMENT OF F-22 AIR DOMINANCE FIGHTER

The men and women of the 187th Fighter Group at Dannelly Field in Montgomery, Alabama and their commander, Colonel M. Scott Mayes, for their cooperation.

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Ivan Davies

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Without your patience and support this project would never have been possible

Special thanks to everyone around the world who bought or commented on DID products.

Your criticism, enthusiasm and suggestions have been noted

Introduction

Digital Image Design was founded by Martin Kenwright in 1989 and is currently based in Warrington, UK. It employs around eighty developers who specialize in all areas of software and simulation, including Artificial Intelligence, Aeronautics and 3D graphical design. Part of the success of the company hails from the fact that individual members of DID have been involved in more than half of all home computer combat flight simulations ever made. Some of DID's previous products have been leaders in their field. F-29 retaliator established DID as a serious contender in flight simulation. Then came TFX, which brought Flight simulation to a wider range of gamers than any preceding simulations had. The ground-breaking EF2000 followed. Hailed as the best fast jet sim ever, it has now become a firm favorite amongst home and network players alike. With the release of DID's F-22 Air Dominance Fighter, the DID philosophy remains Innovate, not Imitate.

Principal Activities

The main area of DID's expertise is that of real-time 3D entertainment technology. With one of the most powerful and evolved 3D engines, DID products have led the field in terms of visual and technological content. Due to the advent of Processor and 3D graphics card technologies, DID are now working more closely with hardware companies in order to maintain a lead in the market. With new systems being developed in-house, it is certain that future releases will maintain the highest of standards available in the field of real-time simulation. This is coupled with close ties to military and civilian advisors who enable DID to ensure accuracy within all products.

Commercial Military Simulations

Digital Image Design's commitment to excellence within the field of combat simulation has led the company into the military arena. Following interest from all three armed services, DID worked towards and attained BS EN ISO 9001 TickIT accreditation in 1997. The first (and currently only) entertainment software company to achieve this qualification. As a result, DID has since developed a range of military training systems, including TIALD laser designator trainers, Cockpit, Night vision and gunnery training systems. Knowledge from all these systems has been declassified and used to improve the quality and realism of subsequent DID releases.

DID Softography

Below is a list of previously released DID products:

F29 Retaliator	**(PC, Amiga, ST) - 1990**
Robocop 3	**(PC, Amiga, ST) - 1991**
Epic	**(PC, Amiga, ST) - 1992**
TFX	**(PC) - 1993**
Inferno	**(PC) - 1994**
EF2000	**(PC) - 1995**
Tactcom	**(PC European release) -1996**
Super EF2000	**(Win 95 European release) -1996**
EF2000 V2.0	**(Win 95 & DOS U.S. release) - 1997**
F-22 ADF	**(Win 95) -1997**
Total Air War	**(Win 95)- 1998**

F-22 Air Dominance Fighter

20th November 1997
Version 5.108

Thank you for purchasing F-22 Air Dominance Fighter. This file contains the very latest information on installing and running F-22 ADF. Please read carefully before installing the product.

1. Setup Issues

Windows 95 and Direct X5

F-22 ADF has specifically been designed to take advantage of the features provided by Windows 95. F-22 ADF requires the 'Direct X5' component of Windows to operate. The F-22 ADF setup program can install this for you.

Windows NT

F-22 ADF can run under Windows NT 4.0 if it has Direct X5 (or above) compatibility. This can be installed on to a Windows NT 4.0 system using the 'Service Pack 3' upgrade.

System Requirements

Minimum specification:
F-22 ADF requires at least the following system configuration:
CPU: Pentium(R) P133 or equivalent
RAM: 16Mb.
HD SPACE: 70Mb (20Mb for the installation + 50Mb Free Space)
CD: 2 x CD-ROM drive.
VIDEO: 800x600 in 16bits (65536 color) on the Windows desktop.
SOUND: Sound Blaster 16 compatible or Windows Sound compatible sound card.
MOUSE: Microsoft Mouse or other Windows '95 compatible device

Recommended specification:
CPU: Pentium(R) P200 or higher
RAM: 32Mb
HD SPACE: 205Mb (155Mb for the installation + 50Mb Free Space)
CD: 8 x CD-ROM drive.
VIDEO: AGP bus based 3D accelerator video card
SOUND: Creative Labs AWE32 or AWE64 card with 512k of memory.
MOUSE: Microsoft Mouse or other Windows '95 compatible device

For Multiplayer:
MODEM: 2 players over minimum 9,600 BPS modem.
A 28,800 modem is highly recommended.
NETWORK: 2-8 players over Windows compliant network.
SERIAL: Both machines must use the same parameters in the dialog box
(Discounting COM port number).
TCP/IP: The joining players must provide the 4-dot IP address or the
domain name of the host computer.

2. Windows AutoPlay

Some Windows 95 machines do not support AutoPlay. If this is the case with
your system you will need to double-click on the icon for your CD-ROM \ DVD
drive to install the game. The CD-ROM \ DVD icon can be found in
'My Computer'.

3. Installation

The F-22 ADF setup program should run automatically on insertion of the game CD-ROM disk into the CD-ROM drive of your computer.

Depending on the country you are in and whether you have F-22 ADF installed already, one of three things will then happen:

* An interface screen with the flags of America / England, France, Germany, Spain and Italy will appear. Select the flag corresponding to the language you speak.

* A screen appears with legal information on it. Select 'Next' to install F-22 ADF.

* A screen appears informing you that F-22 ADF is already installed on your system.

If F-22 ADF is already installed on to your computer then you will be asked if you want to run F-22 ADF, alter the game configuration or reinstall the game.

If you chose to install the game follow the simple on screen prompts. Refer to the F-22 ADF manual for more detailed installation instructions.

4. Uninstalling F-22 ADF

Select the "Add/Remove Programs" from the Control Panel and highlight "F-22 Air Dominance Fighter" component before clicking the "Add/Remove" button. This will remove the main F-22 ADF program and data files. However files created by the user while playing the game (such as ACMI files) will remain. These can be manually deleted.

5. Notes On CD-ROM and DVD Drives

If you perform a 'Typical' installation on your machine you do not require the F-22 ADF CD to be present in the drive to execute the F-22 ADF program. However if you have 'Music' selected you may notice a loss of quality withoutthe presence of the F-22 ADF CD.

If you perform a 'Minimal' installation the F-22 ADF CD is required in the drive to play the game. If you have multiple CD-ROM or DVD drives you must place the CD-ROM in the drive from which F-22 ADF was originally installed.

The CD-ROM is also required to be present if you perform a 'Custom' installation and do not select the 'DID.DAT' data file for installation.

6. Voodoo Graphics Users

F-22 ADF supports 3Dfx Glide 2.43 and higher. Voodoo Graphics users must have this updated version of Glide installed on their system. To install the updated Glide run time driver kit, run the grt243.exe file in the 3Dfx folder of the F-22 ADF CD.

7. Voodoo Rush Users

As with Voodoo Graphics, Glide 2.43 or higher is required to run the Glide version of F-22 ADF. You should also obtain up to date DirectDraw/Direct3D drivers, as those included with DirectX 5 may cause problems when switching between in game 3D and the user interface. These should be available from your vendor, the card manufacturer's web site or 3Dfx's web site.

8. Windows 95 Keyboards

Newer keyboards have 'Start' and 'Windows' keys. If you have problems with these keys disrupting play by returning you to the Windows desktop you can disable them using a program called DOSWINKEY. This can be found on the following Internet site:
http://www.microsoft.com/windows95/info/kerneltoys.htm

9. Game Crash Issues

If at any time during the game, you experience a crash, we recommend you reboot your system before you try to restart the game. If you do not reboot your system, you may encounter problems caused by the original crash.

10. Game Performance

The F-22 ADF program is very intensive on memory, hard disk and CPU. Before running the game it is strongly recommended that you close all other applications.

The more memory you have available the less time the program will spend accessing the hard disk. 32mb of RAM is a fair amount to have but the game will take advantage of more.

For best performance accessing game data from the hard disk perform a 'typical' installation or ensure that the DID.DAT is installed on the hard disk using a custom installation.

If you suffer from prolonged loading periods try de-fragmenting your hard disk using the Microsoft de-fragmentation tool. This can be accessed from the start menu by selecting 'Run' and typing 'defrag' [Return].

You can also reduce loading times by having a permanent swap file on a separate physical drive to the drive that F-22 ADF is installed. Changing the configuration of the Windows swap file should only be undertaken by advanced users. DID will NOT accept responsibility for any problems caused by changing Windows configurations.

The frame rate of the program is determined by the resolution, graphical detail, video card and processor speed. Running the game at a resolution of 800x600 is not recommended on any machine with less than a 200MHz Pentium(R) processor. If you find that the frame rate is low with the 640x400 resolution then try removing graphical detail in the options screen; if the frame rate is still too low then try dropping the screen resolution to 320x200.

If you find that the frame rate drops dramatically when explosions are taking place then try reducing the explosion detail in the options screen.

Some video cards don't give very good performance via Direct 3D. You can improve performance with these cards by switching to software rendering in the options screen.

11. Sound Cards

Music:
To get the best form the in-game music you need an AWE 32 or better, with at least 512k of RAM on board. Make sure that the AWE card's Wave Effects Synthesis option is selected as the default MIDI device in the Control Panel Multimedia settings. To check, go to

Start->Settings->Control Panel->Multimedia->MIDI, and select
MIDI for Creative Advanced Wave Effects Synthesis.

Speech:
The speech requires that the DSP Group TrueSpeech decompression CODEC is installed. This is normally installed by default by Windows 95 setup, but may not be on your system. To check this, go to

Start->Settings->Control Panel->Multimedia->Advanced->Audio Compression Codecs. If the DSP Group Codec is not there you will need to install it from your Window 95 setup disk. To do this go to

Start->Settings->Control Panel->Add Remove Programs->Windows Setup.

Double-click on Multimedia (you may need to scroll down) and make sure Audio Compression is checked. Press OK, and follow the instructions from Windows.

Cockpit speech may be disabled by setting BETTY=0 in the game.cfg file.

12. Joysticks

F-22 ADF can be controlled using keyboard but we strongly recommend that you play with a joystick. F-22 ADF will make use of whatever joystick device is currently configured through Windows. Consult the "Flight Sticks and Controllers" section of the F-22 ADF manual on how to configure joysticks in Windows.

This product does not currently support the force feedback features of joysticks such as the 'Microsoft Sidewinder Force Feedback'.

13. ACMI

Files from the ACMI feature of the game are saved by default in the ACMI directory of the F22 installation. These '.ACM' files can be exchanged with other F-22 ADF players. Simply copy the files in to the ACMI directory on the target machine.

14. Manual Addenda

Difficulty Levels:
The difficulty of the game can be set in the game options screen. The three difficulty options determine the accuracy of weapons fired against your aircraft, the accuracy of your guided weapons and the amount of damage taken by your F-22 when hit.

Runway Padlock View:
When the HUD is in ILS mode the 'F2' key (target padlock view) will now padlock to the runway you have been instructed to land on. Pushing 'F2' again will show an external view of your plane with the runway behind. You will be unable to use this view if you are out of range of the landing strip or if no runway has been allocated to you.

View Zoom:
On some machines holding shift and '7' or '1' keys on the numeric keypad does not reposition the camera. This problem can be resolved simply by turning off the 'NumLock'.

Snap Throttle:
On some machines hitting Shift '+' and Shift '-' on the numeric keypad to snap open and snap shut the throttle may not function. This problem can be resolved simply by turning off the 'NumLock'.

Rotating the Camera around objects in external views: If you are playing the game with joystick then the cursor keys will be used for moving the camera. However if you control the F-22 using keyboard the cursor keys will be used to control aircraft pitch and roll.

Wingman Padlock views:
Page 108: The 'F5' key now puts the game into 'Wingman Padlock' View.
Page 160: The 'Shift-F5' key combination now puts the game into 'External View Wingman to Player' view.

Chaff and Flare release:
Insert and Delete both launch either Chaff or Flare or both depending on the types on missile locked on to you. If there are no missiles inbound then the keys do nothing. The ':' and '@' countermeasures keys are unaffected.

Cannon Snake:
When using the Air-to-Air cannon, the path of the shells is shown as a moving 'snake' on the HUD. At the end of the 'snake' is a circle. If the circle is over the targeting box of the enemy aircraft then your bullets have a high probability of hitting.

Launching Missiles:
When using radar guided Air-to-Air missiles (such as the AIM120 AMRAAM) you must have an EMCON level at least 3 to launch. These weapons can not be launched at EMCON levels 1 and 2.

Emergency Landings:
If your aircraft has damaged under carriage you may have to perform an emergency 'belly' landing. For safety reasons we recommend jettisoning all stores before attempting a belly landing.

Exiting The F-22 ADF Program:
The program can be exited by selecting 'Quit' from the main F-22 menu. The F-22 ADF manual has several screen shots with 'Quit' icons shown in the title bars. These icons have since been removed from the product.

AWACS Missions:
AWACS missions end when the last Allied AWACS in theater is destroyed or lands at an airbase.

The AWACS 3D Window:
When the flight being viewed in the 3D AWACS window is destroyed, the view remains focused around the last recorded position of that flight. In order to update this view, the player must select another flight in the AWACS map window.

AWACS and Re-centering the Window:
Pressing the Center button zooms the map to the current AWACS combat zone and can be used to zoom quickly out of the map.

The AWACS FEBA Button:
Pressing the FEBA button displays the AWACS combat zone and the FEBA between the warring nations.

The AWACS Message Window:
When the AWACS sends or receives a message, the sender is displayed in the small window adjacent to the message window. Clicking with the left mouse button on this window will center the map about the flight sending that message.

Targets in AWACS missions:
While in AWACS missions on Easy and Medium levels the mission targets are highlighted with a red box.

Accessing the F-22 Help File Within The Game: The Alt-F1 key combination no longer calls up in game help. The help file is accessed from the main menu option or from the question mark icons in the windows title bars.

Padlock Views:
When changing from air-to-air weapons to air-to-ground weapons the view padlock filter is automatically set to 'ground mobiles'. When changing from air-to-ground to air-to-air weapons the filter is set to 'aircraft'. This can be overridden with the F11 key.

Changing Detail Settings:
Changing the detail of the graphics within the game can be performed from the Options screen or by pushing 'Shift-D'. This key combination cycles though Low Detail, Medium Detail, High Detail and Custom Detail.

Auto Target Cycling:
Auto target cycling can be toggled on and off by using 'Shift-C'.

Shoot List:
The shoot list can be cleared with the 'U' key. This is useful in situations where you build an automatic shoot list and then need to clear to build a manual shoot list.

Kill Boxes:
Kill Boxes are shown as red boxes on the 'Situation' and 'Attack' MFDs. Any ground based unit (tanks and SAMs etc.) contained by the box are to be regarded as the enemy. The box is also shown on the briefing map and on the in game map (accessed using the 'del' key on the numeric keypad).

Mission Targets information in the HUD:
When playing a given mission, targets that are required to be destroyed in order to complete the mission are now shown with the letter 'T' adjacent to them in the HUD display. The 'T" cue is only shown in the HUD on the Easy and Medium difficulty levels and is not present when playing at the Hard difficulty level

setting. Mission objectives can also be viewed from the in-game map by pushing the 'Del' key on the numeric keypad.

Mission Target information in the Defense, Situation and Attack displays:
On Easy and Medium levels in the game the targets that are required to be destroyed are shown with the letter 'T' in the target information. The target information is shown when you position the mouse cursor over an aircraft symbol in the Situation, Defense or Attack displays. The flight call sign is also shown. This is the same call sign that is shown in the mission objectives.

Pilot Aids:
Pilot aids overlays the Situation and Defense displays in the bottom corners of the screen. The pilot aids default to on in the 'Full HUD' view and their settings can be adjusted by pushing 'Alt-G'. The three settings are:
* Full HUD pilot aids (Default)
* Full HUD and virtual cockpit pilot aids
* Pilot aids off

Setting the game's difficulty level:
F-22 ADF's difficulty level can only be set from Options, selected from the main menu. The in-game Options screen (accessed by selecting Shift-O) will not allow you to change difficulty level.

Gamma correction when playing the Glide (3DFx) version:
Gamma correction with the Glide version is performed from the 3DFx configuration programs resident in the Windows 95 Control Panel. Refer to your video card documentation for specific set up information.

The HUD Terrain following box:
To allow your F-22 to fly at low level your HUD shows a rectangle at the bottom of the

display. As your plane flies lower the rectangle rises up the display. If you keep the velocity vector in or above the box then your plane is in no risk of hitting the ground.

Removing HUD Clutter with the 'J' key:
The 'J' key can now be used for removing clutter from the HUD to allow you to concentrate on the target at the head of your shoot list. The 'de-clutter' is a toggle on/off function and when toggled on turns off the following symbology in the air-to-ground and air-to-air HUD modes:
* Velocity vector
* The HUD Terrain following box
* Targets that are not currently at the head of the shoot list
* The radio frequency indicator
* The EMCON indicator

Landing at Friendly airfields to rearm and refuel:
You can land at friendly airfields to rearm and refuel your plane. Land as normal on the runway, bring your plane to a halt and you will be rearmed and refueled.

Throttle Sticks and Auto-pilot Refueling:
When playing with a throttle stick you may encounter a problem with auto-pilot refueling. This problem is caused when the throttle is set to minimum when the auto-pilot connects to the refueling boom – the plane may disconnect from the boom prematurely. We recommend keeping the throttle at a medium setting until the auto-pilot refueling operation is complete.

Quick Combat:
The Quick Combat briefing incorrectly states that the rearming period for the weapons on the plane is 15 seconds. It is actually 30 seconds.

15. Troubleshooting

"F-22 ADF does not take advantage of my 3D accelerator card using Direct 3D":
F-22 ADF is graphically very demanding and some graphics cards do not have the capabilities required by F-22 ADF for hardware acceleration via Direct 3D (D3D).
When the F-22 ADF program starts it examines the capabilities reported by the DirectDraw/Direct3D driver(s). A number of basic requirements are checked against to determine whether or not the 'hardware' option should be made available on a particular system. If the requirements are met then the 'hardware' option will be available in the options screen. These prerequisites are:
* Video memory (a minimum of 4mb is required if AGP is not present).
* Specific fogging effects (fog vertex).
* Alpha blended textures.
* Perspective corrected texture mapping.
* A 16bit colour D3D driver.

"F-22 ADF displays the error 'Unable to create a 16 texture surface' when I select a mission":
This error occurs when using Direct 3D if your video card is incapable of playing the game with 3D acceleration. To solve the problem reload the game and select the options screen from the main menu. On this screen is a software rendering option, selecting this will solve the problem.

"While playing F-22 ADF the game frequently accesses the hard disk":
This is because the F-22 ADF program uses the Windows swap file when your PC does not have enough main RAM to contain the whole game. The situation can be improved with the following measures:
* Add more RAM to your PC.

* Turn off speech
* Turn off sound effects
* De-fragment your hard disk (this may have negligible effects)

“When I run the game it gives the error ‘Dibsection creation failed’”:
If you receive this error message when running F-22 ADF it means that not enough memory is available to the program. This problem is easily solved by freeing up space on your hard disk. Approximately 50-120 megabytes of free space is required to run F22-ADF. This amount varies depending on machine RAM and your installation options.

“When I run the game it gives the error ‘Not enough memory for file‘”:
This error is caused by lack of swap space. See the previous paragraph for more details.

“I can’t free up enough space on my hard disk for the swap file to play the game”:
Change the game options to turn off speech and sound effects. This may reduce the swap space requirement of the game to the point where it can be run on your particular PC.

“I can not change my in game options because I don’t have enough free space to run the game”:
Re-run the F-22 ADF installation program from the F-22 ADF CD-ROM. Select the option to change game options and then make your adjustments. You can also change game options by manually editing the game.cfg file which is present in the program directory.

“F-22 ADF takes a long time to return to the Windows desktop after quitting”:
This is because the F-22 ADF program requires a lot of swap space. Windows recovers this space before returning you to the desktop.

“F-22 ADF Does Not Work With My Joystick”:
Your joystick must be configured using the 'Game Controllers' section of the Windows control panel. The joystick that you intend to play with must have a Controller ID of 1. The controller’s ID can be viewed by clicking on the Advanced tab of the ‘Game Controllers’ window.

“Power management causes problems with my computer when running F-22 ADF”:
Certain PC configurations may experience problems with power management while playing F-22 ADF. If your machine has problems then refer to the technical documentation supplied with your computer or contact the vendor who supplied your PC.

“My joystick ‘drifts’ when I play F-22”:
The Windows 95 joystick calibration system does not store a center point for the calibrated device. This can cause ‘joystick drift’ which prevents your plane from flying level when the joystick is in its central position. Pushing ‘Alt-C’ in flight while your joystick is centered should solve this problem.

“The game crashes when I receive an email message”:
This problem has been reported on machines using Novell NetWare when playing F-22 with a 3D accelerator card. This problem can simply be solved by logging off your network. The multi-player game will still be accessible when you are logged off.

“The screen display is not centralised on my screen.”:
On some video card and monitor combinations the display modes used by F-22 ADF can cause the screen to appear offset. This problem can be simply solved by adjusting your monitor controls. Please refer to your PC documentation or PC supplier for more information.

“F-22 ADF is compressed on my monitor.”:
On some video cards the 640x400 display mode has borders at the top and bottom of the screen display. Selecting a different screen resolution from the options screen menu will resolve this problem.

“I am experiencing problems with Multiplayer.”:
There is a patch for the DirectPlay component of DirectX in the extras directory on the CD-ROM.

Glide and Cyrix Processors (lock ups):
There has been a problem reported where the Glide version of F-22 ADF periodically locks up on some machines with Cyrix microprocessors. If you experience this problem you will have to install the Direct3D version to use hardware acceleration.

16. F-22 Updates and Patches

Any F-22 ADF updates that are made will be available from the internet at:

http://www.did-us.com

18. Feedback

Let us know your thoughts about F-22 ADF. Many features (such as the ACMI) were developed as a result of feedback from our EF2000 product. You can contact the F-22 Development team directly:

19. Useful Information

The DID web site contains a wealth of information and is an excellent starting point for virtual fighter pilots on the Internet. Point your browser at:

http://www.did-us.com

This site contains links to F-22 and combat flight simulator related information.

F-22 Air Dominance Fighter Patch (V5.144)

Wednesday, March 5, 1998

Thank you for obtaining the F-22 ADF Patch. This Patch will upgrade your installed version of F-22 Air Dominance Fighter to V1.544.

Notes for nVidia Riva 128 Video Card Users
Users of the nVidia Riva 128 who replace this device with another video card will have to remove or rename the 'nvidriva.128' file which is present in the 'DID\F22ADF\program' directory (or wherever F-22 ADF was installed to). If this file is not removed then visual anomalies may be present when running F-22 ADF on the new video card.

Notes for Users with Voodoo II Chipset Based Video Cards
The problem which prevented the 3Dfx\Glide version of F-22 ADF working with Voodoo II chipset cards has now been fixed in this version.

Notes for Users with Permedia II Chipset Based Video Cards
There has been a problem reported with Permedia II chipset cards during the testing of this version. If, while flying the plane, you enter into the options menu (shift + 'O') and return to the main game you will experience graphical anomalies. To prevent the problem we recommend that the options menu screen only be accessed from the main menu.

Bugs That Have Been Fixed
The following bugs have been fixed within F-22 ADF:

* The LANTIRN zoom problems when LANTIRN is slaved have been fixed.

* The problem caused by requesting refuel twice has been fixed.

* The inter-plane collision on the ground has been fixed. Planes would not collide if the player was moving very slowly.

* The vocal warnings cockpit switch to turn off Bitchin' Betty from the Systems MFD has been fixed.

* Wingmen now ignore formation commands when they're on the ground.

* View padlock no longer padlocks onto player's plane.

* The lock-up when exiting the game while ACMI is still recording has been fixed.

* The crash which would happen sometimes upon selecting LANTIRN has been fixed.

* The crash to do with having a static target in your shoot list and looking down at the right-hand MFD has been fixed (thanks to Ray 'Viper' Purvis for letting us know about that one).

* The crash caused by pressing 'Z' after ejecting has been fixed.

F-22 ADF Multi-player and Communications
Please note that the patched version of F-22 ADF will not communicate with the original release.

The following changes have been made to the multi-player section of the game

1. Improved multi-play connectivity using TCP/IP and IPX over services such as KALI95.

2. Improved plane position prediction to reduce warping.

3. The bug that occurs when the server cancels the DirectPlay dialog box which causes the selected service provider not to reset correctly has now been fixed. It now resets the selected service and screen correctly.

4. The client's (game joiner's) multi-player details screen now resets each time a new scenario is selected. It displays the correct number of team buttons and weapons list.

5. The amount of data being sent across all media has now been reduced. This prevents high specification machines swamping lower specification machines with data.

Connectivity Instructions for each DirectPlay Service Provider
Follow the instructions provided below that are appropriate to your connection method.

IPX
Select IPX Connection For DirectPlay.

Host: Select new game button.
Wait for the others to join.
Joiner: Select the game from the 'Games in Progress' list.
Select the join game button.

TCP/IP
Select TCP/IP Connection For DirectPlay.

Host: Select new game button.
Wait for the others to join.
Joiner: Select join game button, a window will appear.
Enter the IP address or the DNS of the host machine.
Select the game from the 'Games in Progress' list.
Select the join game button.

Modem
Select Modem Connection For DirectPlay.

Host: Select new game button.
Select the correct modem from the list in the dialog box.
Click the 'Answer' button in the dialog box.
Wait for the other player to join.
Joiner: Select the join game button.
Enter the telephone number of the host machine.
Select the correct modem from the list in the dialog box.
Click the 'Connect' button in the dialog box.
Select the game from the 'Games in Progress' list.
Select the join game button.

Serial
Select Serial Connection For DirectPlay.

Make sure that the settings in the Serial Connection dialog box are the same for both machines (except port number). (e.g. Baud Rate: 57600, Stop Bits: 1 bit, Parity: No Parity, Flow: RTS/DTR).

Host: Select the new game button.
Complete the settings dialog box.
Wait for the other player to join.
Joiner: Select the join game button.
Complete the settings dialog box.
Select the game from the 'Games in Progress' list.
Select the join game button.

Graphics Cards Issues
The following graphics cards are supported by Direct 3D in addition to the cards supported in the initial F-22 ADF release. Please note that graphical anomalies may periodically occur on some of these products due to driver and hardware problems.

* Cards based around the Permedia and Permedia II chipsets

* Cards based around Nvidia Riva with PCI bus (this previously only worked with AGP)

* Cards based around the ATI Rage Pro with PCI bus (this previously only worked with AGP)

* Cards based around the Rendition V2200 chipset.

In addition problems have been found on the following cards:
* Serious graphical anomalies on Power VR chipset based machines when using Direct 3D.

* Problems have been found in test with Power VR or Rendition chipset cards involving the fogging effects.

What's New?
There are many game play enhancements that have been included in his upgrade which make F-22 ADF more enjoyable to play. The following enhancements have been made:

There is now a realistic fire delay between SAMs locking on and firing at you. They previously launched instantaneously.

The sensor range is no longer changed when you switch to manual Emcon levels.

SMART PILOTS controlled aircraft now have a realistic number of cannon rounds as found in the actual aircraft.

A systems display for wingmen has been added to allow you to view their weapons and fuel status. Click the 'WS' button in the system display to cycle through each of the wingmen.

The wingmen and wing-leader damage status can now be seen at a glance on the systems display. Status is shown by the color of the wingman text. White is fully functional, yellow is damaged and red usually means imminent use of the Ejector seat. If any of the pilots in your flight are shot down then they will be removed from your systems display.

The shoot list generation and target prioritization's have been improved. The system will now prioritize targets in center of HUD higher than the other potential threats. To prioritize something higher, place it in the center of the HUD, and press 'T'.

Cluster bombs have been adjusted so that they deploy when they reach a certain altitude. They used to deploy bomblets after a given time making it impossible to use them at low-level effectively.

There has been a blast radius added to the bombs. Bombs will now damage ground vehicles and planes in close proximity, not just those hit (don't drop a bomb too low now!).

The 'zoom-out' in Satellite view has been increased.

The damage modeling has been adjusted. Cannon rounds now do much less damage to buildings, as do MK20s.

The manual adjustment of auto-pilot values in the Auto-pilot display has been adjusted to speed up the rate of change of the values.

The weapon selection system has been modified. Previously when last AIM120 was released Cannon would be selected. Now, AIM9Xs are selected if present.

The padlock views can no longer be used to padlock planes outside of visual range. You can still use target padlock though, since your Helmet Mounted Display avionics are showing you the location of the target.

A range value has added to the superimposed MFD displays in full screen HUD.

The missile damage for AIM9Xs and AIM120s has been adjusted.

The Radar guided missiles and SAMs are now slightly easier to spoof in medium and hard difficulty levels.

A wider selection of HUD colors has now been added. The HUD color is now saved between game loads.

A vertical speed indicator value has now been added to ILS HUD. (VSI – in feet per second)

The plane damage code has been adjusted – planes won't disintegrate quite as often, and the player's MFDs won't all get knocked out together.

Cluster Airfield – The target view in the briefing now shows a picture of the hangar which must be destroyed instead of the control tower. Finding the hangar used to be trial and error.

Current wide angle views are now saved when you exit the game.

If the airbrake is damaged, wheel brakes still work.

The difficulty has been adjusted in following missions: CAP UK, Raid Egypt and Cluster CAS.

Alt C (joystick center) settings are now saved when you exit the game.

You don't need to kill the throttle completely now to detach from the refueler.

The aspect marker in HUD has been adjusted so it works correctly when tracking a target over the shoulder.

The throttle noise is now louder when afterburner engaged.

A new speech quality option has been added to the options screen.

Changed expansion strip thumping noise so that it only occurs on taxiways – not on runways.

Missile trails can now be seen at a greater distance.

Getting Started

Getting Started